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INDEX.

PAGE

A

Abrasion Tests, Inst. M.E. Research 497
Acetylene, Explosibility of.. 127
Acetylene, Liquid Use for Welding 180
Acid-resisting Alloys 170
Acoustic Properties of Buildings 212
Air Compressor, Reavell and Jones 219
Air Compressor, Reavell's Two-stage 137
Alcohol, Effect on Health of Workmen 133
Alldays & Onions' Crucible Tilting Steel Furnace..... 59
Alloys, Acid-resisting 170
Alloys for Fusible Plugs..... 113
Alloys, Non-ferrous, for Locomotives 168
Alternators, Cooling of 14
Alternators, Synchronising 16
Aluminium-Bronze, Heat Treatment 148
Aluminium-Bronze, Tests of 148
Aluminium Castings and Forgings, Strength 504
Aluminium Chips, Melting of 452
Aluminium, Effect in Steel.. 298
Analysis, Chemical, of High-speed Steel 5
Angular Measurement, Minute, A. Strasey 156
Annealing Furnace with Surface Combustion 289
Anthony, Fuel Economy in Locomotive Boilers 461
Apprentice System in the Electrical Trade 308
Apprentices, Education of... 184
"Aquadag" Graphite Lubricant 479
Armstrong-Whitworth Steel Ingot Mould 377

B

Babcock, A. H., Corrosion in Boilers 119
Bailey, Steam Flow Measurement 363, 380
Bailey's Reducing Valve ... 191
Baker's Steam Trap 214
Balancing, Electric Plant.... 17
Baldwin Locomotive Company, Mikado Type of Locomotives 203
Ball and Roller Bearings ... 235
Balmforth's Electric Furnace 329
Barham, G. Basil, on Good and Bad Lubricants 27
Batho, C., Partition of Loads in Riveted Joints... 455
Bearing, Experiment with Friction of 236
Bell, Sir Hugh, Address on Trade After the War... 34, 60
Belts, Steel, for Driving..... 106
Bessemer Steel Process, Rise and Decline 213
Blastfurnace Accidents 423
Blastfurnace Charging Bell 91
Blastfurnace, Distribution of Materials in 29, 43
Blastfurnace Gas, Effect on Wrought Iron 255
Blastfurnace Hoppers, Construction of 43

PAGE

Blastfurnace Slag, Utilisation of 209
Bleeder Turbines 85
Blower, Keith's Rotary 22
Boiler Ash Removal Plant... 40
Boiler Corrosion, A. H. Babcock 119
Boiler Coverings, Hints on... 9
Boiler, Deighton's 458
Boiler Draught, Induced 450
Boiler Evaporation 41
Boiler Expansion, Experiments in 468
Boiler Explosion at Manchester 373
Boiler Explosion, Compound 273
Boiler Explosions, Annual Report for Years 1914-15 14
Boiler Firing with Bituminous Coal 150
Boiler Furnaces, Management of 150
Boiler-house Design, W. W. Lackie 39
Boiler Plant, Large, Efficiencies of 42
Boiler Plates, Temperature 13
Boiler Problems and Their Solution, B. Thompson ... 7
Boiler Scale 119
Boiler Steam Pipes, Defects 9
Boiler Tubes, Crystallisation 100
Boilers, Cleaning of 7
Boilers, Corrosion of from Leakage 9
Boilers for Waste Heat..... 510
Boilers, Fuel Economy in, Stromeyer 400
Boilers, Gas-firing, Efficiency 141
Boilers, Gas-firing of ...394, 373
Boilers, Gas-firing, Temperature of Furnace 141
Boilers, Heat Transmission.. 13
Boilers, Locomotive, Bulging of Front Flue Sheets.. 28
Boilers, Locomotive, Care of 126
Boilers, Locomotive, Combustion in 461
Boilers, Locomotive, Design and Maintenance 54
Boilers, Locomotive, Treatment of Feed Water 17
Boilers, Multi-tubular, Expansion of 468
Boilers, Non-conducting Coverings 135
Boilers, Oil-fired, Manipulation of Burners 375
Boilers, Overheating from Grease 7
Boilers, Testing of 41
Bonus System of Wages, G. Stoney 182

Book Reviews—
Aeronautical Engines, Balancing. Kean 275
Applied Mechanics. Jamieson, 10th Edition, Vol. I. 195
Arithmetic for Engineers. Clapham 195
British Prices, Weights and Measures, and Foreign Conversions. Winzar 376
Centrifugal Pumps and Suction Dredgers 3
Dynamo and Motor Attendants and Their Machines 275

PAGE

English and American Tool Builders. Roe 274
Fans, Theory and Practice. Innes 274
Framed Structures. Johnson and Bryan 195
Gas and Oil Engines. Garrard 195
Gas Engine Ignition. Norris 195
Heat Treatment of Tool Steel. W. Brearley ... 3
Illinois Coals 376
Large Electric Power Stations 3
Masonry Dam Design. Morrison 195
Mathematics for Engineers. Karapetoff 275
Power Transmission by Belts. Kent 494
Principles of Electrical Engineering. Kapp ... 274
Ruler and Compasses. Hudson 195
Salesmanship. Goddard... 376
Slide Rule. Higgins 494
Soldering and Brazing. Jones 376
Spon's Electrical Pocket Book 494
Stresses in Structures. Heller 494
Strength of Webs of Beams 195
Telegraphy. Herbert ... 376
Water Power of Canada... 195
Wire and Sheet Gauge Table. Stobbs 494
Boring Machine, Feeding Device, Rose, Down, and Thompson 309
Boring Mill, Webster and Bennett 206
Boring Mills, Webster and Bennett Control Mechanism 379
Borings, Melting of in Cupola 321
Brass, Arsenical Annealing 218
Brass Castings, Cleaning of 291
Brass Castings, Composition for Sound Work 294
Brass Castings, Effect of Aluminium 294
Brass Castings, Use of Chills 294
Brass, Effect of Cadmium 27, 218
Brass Furnace, Davis and Twigg 467
Bricks, Insulating Properties of 185
Bridge Lifting at Keadby ... 430
Bridges, Use of Bronze in.... 50
British Association Report on Coal Economy 353
British Association Report on Fuel Economy 219, 238
British Engineering Standards, Influence on Design 206
Bronze-Aluminium, Heat Treatment of 148
Bronze-Aluminium, Tests of 148
Bronze, Strength of 50
Bronze, Use in Bridges 50
Bronze, Use in Trunnions and Bearings in Bridges... 50
Bronze-Zinc, Strength of ... 10
By-product Recovery from Coal Carbonisation 441

PAGE

C

Cables, Electric, Losses at High Frequencies 114
Cables, Electric, Manufacture of 115
"Ca' Canny" in Workshops 193
Cadmium, Effect in Spelter 218, 241
Cadmium, Effect on Zinc ... 149
Cadmium, Effect on Zinc and Brass 27
Calcium, Production of 83
Capital and Labour, Division of Profits 34, 60
Capital and Labour, Profit-sharing 194
Carbonic Acid, Comfort and Ventilation 24
Cargo-handling Appliances, J. Forrest Lecture 347
Case Hardening with Oxy-acetylene Flame 478
Cast Iron, Effect of Casting Temperature 477
Cast Iron, Effect of Heat Treatment 476
Cast Iron, Effect of Silicon 477
Cast Iron for Engine Cylinders, Hurst 459, 475
Cast Iron, Frictional Surfaces of 458
Cast Iron, Growth of, in Superheaters 475
Cast Iron Thermal Reactions, Turner 389
Central Power-station Efficiencies 42
Central-power Station Equipment at Johannesburg ... 14
Centrifugal Blower, Keith's 22
Centrifugal Governors, Hartnell's 17
Charnock, Prof., Uniform Driving in Textile Mills... 293
Chimney and Mechanical Draught 450
Chorlton & Ruston, Six-cylinder Rotary Oil Engine 248
Chromium, Effect on High-speed Steel 5
Chromium, Nickel Steel 137
Chromium, Production of ... 83
Cleaning of Brass Castings.. 291
Clerk, Dugald, Gas Engine Development 433, 436, 469
Clerk, Dugald, on German Competition 333, 339
Clutches, Friction, W. Gass 342
Coal, Bituminous, Preparation of, in Illinois 396
Coal, Carbonisation and By-product Recovery 441
Coal Consumption of Steam Engines 401
Coal Consumption per I.H.P. in Steam Engines 354
Coal-dust as Fuel 200
Coal-dust Furnaces for Metallurgical Work 256, 276
Coal-dust Furnace, Holbeck's 146
Coal-dust, Spontaneous Combustion of 257
Coal Economy, British Association Report 353
Coal-handling Appliances.... 347
Coal, Powdered, as a Fuel 420, 429
Coal Purchase on Calorific Basis 41

389543

PAGE
Coal Resources of United Kingdom ... 95
Coal, Statistics of Industrial Use, British Association Report ... 220
Coal, Testing and Purchase 394
Coal, World's Resources of.. 220
Cobalt, Effect on High-speed Steel ... 5
Coke Oven Gas, Power from 234
Coke Prices, Official ... 48
Cole, Marchant, & Morley, Air Regulating Device for Internal-combustion Engines ... 438
Collieries, Fuel Economy at 87
Collieries, Power Plant at ... 87
Colliery Explosions, Effect of Stone Dusting ... 237
Combustion, Chemistry of, in Furnaces ... 150
Combustion in Locomotive Boilers ... 461
Commercial side of Engineering ... 357
Compound Boiler Explosions ... 273
Compressor, Air, Reavell's Two-stage ... 137
Condenser, Hick Hargreaves ... 386
Condenser Pump, Hick, Hargreaves ... 428
Condenser Tube Troubles, White ... 84
Condenser Tubes, Velocity of Steam in ... 466
Condenser, Willan's Test of 354
Condensers, Marine ... 411
Condensers, Morison's Air Extractor ... 325
Condensers, Surface, Design of, Orrock ... 465
Converters, Electric, Balancing by means of ... 16
Copper Prices, Jan.-June, 1916 ... 11
Cork, Manufacture of, for Non-conducting Heat Coverings ... 136
Corrosion, Alloys to Resist Acid ... 170
Corrosion, Galvanic, and its Prevention ... 300
Corrosion in Boilers, A. H. Babcock ... 119
Corrosion of Boilers, Causes 9
Corrosion of Pipes, Speller 502
Corrosion of Steel Sheets.... 320
Corrosion, the Electrolytic Theory of ... 146
Cost Accounts for Foundry.. 295
Cost Systems in Manufacture ... 189
Cotton Mills, Effect of Uniform Driving, Charnock... 293
Crane Accidents ... 395
Crank-pin Effort in Oil Engines, Daugherty ... 351
Crankshaft Failures in Diesel Engines ...53, 56
Crossley's Starting Apparatus for Gas and Oil Engines ... 195
Crossthwaite, Earth Pressure in Retaining Walls... 491
Crucible Tilting Furnace, Alldays & Onions ... 59
Crystallisation of Ingots, Brearley ...242, 261
Cupola, Oil-fired ... 155
Cupolas for Foundry Air Supply ... 2
Cutting Tools, Design and Grinding of ... 230
Cylinder Lubrication with Graphite ... 479
Cylinders, Cast Iron for, Hurst ...458, 475
Cylinders for Single-acting Oil Engines, Sulzer Bros. 366

D

Darling, Thermo-electric Properties of Metals ... 92
Daugherty on Diesel Oil Engines ...350, 368
Davidson Two-cycle Gas Engine ... 268
Davidson's Centrifugal Fan 275
Davis & Twigg, Brass Furnace ... 467
Davy's Compound Condensing Pump ... 495
Decimal System of Weights and Measures ... 393
Deighton's Water-tube Boiler 458
Design, Influence of Similitude ... 280
Diamond Turning Tool for Grinding Wheels ... 222
Die-casting Apparatus, Wardle's ... 261
Diesel Engine, Air Compressor Troubles ... 334
Diesel Engine, Crankshaft Failures ... 53, 56
Diesel Engine Lubrication, Daugherty ... 352
Diesel Engine Pistons, Failures of ... 475
Diesel Engine, Use of Tar Oils in ... 6
Diesel Engine Users' Association 6, 53, 56, 69, 334, 439
Diesel Engines and Steam Engines, Economy Compared ... 350
Diesel Engines and Steam Engines in Combination... 6
Diesel Engines, Capital Cost 35
Diesel Engines, Economy of, Daugherty ...350, 368
Diesel Engines for Mine Power Plants ... 186
Diesel Engines, Horizontal v. Vertical, Daugherty 351
Diesel Engines, Piston Lubrication ... 439
Diesel Engines, Starting with Low Compression, Watkinson ... 299
Diesel Engines, Use of Tar Oils ... 334
Dinger on U.S. Naval Engineering Developments 387, 409
Diseases, Industrial ... 133
Distribution of Electricity at High Pressure ... 107
Dividing Engines, A. Swasey 156
Dobson, Johannesburg Power Station Equipment ... 14
Domestic Heating Boilers and Safety Valves... 374
Domestic Heating Problem, Hanssen ... 391
Draught, Mechanical, for Boilers ... 450
Drop-forgings, Heat Treatment of ...6, 71
Dust and Ventilation ... 25
Dust Extractor from Smoke 238
Dust Fuel ...420, 429
Dust Fuel Furnaces for Metallurgical Work ...257, 276
Dust Fuel, Holbeck's Furnace for ... 146
Dust Fuel, Mechanical Stokers and Burners for... 258
Dust Fuel, Spontaneous Combustion of ... 257
Dust Fuel, Use of ... 200
Dust, Stone, Effect in Coal Mines ... 237
Dwelling-houses, Heating and Ventilating ... 391
Dynamometer, Walker's 20
Dyson, C. W., Mystery of the Screw Propeller ... 90

E

Earth Pressure on Retaining Walls ... 491
Economic Distribution of Electric Power on N.E. Coast, Sloan ... 278
Economy in Use of Fuel, British Association Report ...220, 238
Economy of Fuel in Boilers, Stromeyer ... 400
Economy of Fuel in Power Plants ... 353
Education of Apprentices, G. Stoney ... 184
Education of Engineers ... 20
Education of Engineers, Shop Instruction 226, 253
Education, Official Report on Science and Industry ... 49
Education, Scientific and Technical, Value of ... 173
Electric Alternators, Synchronising ... 16
Electric Alternators, Ventilation of ... 14
Electric Cable Losses at High Frequencies ... 114
Electric Cables, Insulation of 187
Electric Cables, Manufacture of ... 115
Electric Cables, Steel ... 314
Electric Distribution for High Pressure ...107, 128
Electric Furnace, Balmforth's ... 328
Electric Furnace for Steel Foundry ... 284
Electric Horse-power, Cost 401
Electric Insulation of Central Stations ... 187
Electric Lamps of High Illumination ... 124
Electric Leakage of Railway Tracks ... 154
Electric Locomotives, Design of ... 501
Electric Machinery, Balancing Arrangements ... 17
Electric Motor and Turbine Combined. Westinghouse 85
Electric Motors, D.C., for Rolling Mills ... 481
Electric Power Distribution, C. M. Mertz ...271, 286
Electric Power Plant, Large, Efficiencies of ... 42
Electric Power Station Equipment at Johannesburg ... 14
Electric Propulsion of ships 157, 409
Electric Railways, Leakage 154
Electrical Apparatus, Defects and Remedies... 177, 187
Electrical Driving in Textile Mills, Charnock ... 293
Electrical Furnace, The Gronwell-Dixon ... 306
Electrical Plant, German, Defects in ... 473
Electrical Power and Fuel Economy on N.E. Coast, Sloan ... 278
Electrical Water Meter ... 76
Electrically Propelled Dreadnought for U.S. Navy 254
Electricity, Economical Distribution ...313, 332
Electricity, Standardisation of Frequency and Voltage 271, 286
Electricity Supply in London Area ... 287
Electrolysis and Corrosion... 146
Electro-magnetic Units, International System of..... 260
Engine Cylinders, Cast-iron for, Hurst ...458, 475
Engine Cylinders, Graphite as a Lubricant ... 479
Engines, Marine, Development of ... 200
Engines, Steam, Coal Consumption ... 401
Engineering Design, Influence of Similitude ... 280
Engineering Standards, British Influence on Design ... 206
Engineering Trades After the War. Board of Trade Enquiry ... 52
Engineering Trades Organisation ...453, 456
Engineering Works, Selling Organisation ... 357
Engineers, Education of ... 20
Engineers, Education of, Shop Instruction in Technical Schools ... 226, 253
Estimating and Costing in Engineering Works ... 337
Evaporators, Heat Transmitting Tubes for ... 171
Exhaust Silencers in Gas and Oil Engines ... 115
Expansion in Boilers, Experiments on ... 468
Explosion of Boilers, Compound ... 273
Explosions in Boiler Flues... 143
Explosions of Boilers, Annual Report, 1914-15..... 14

F

Factory Inspector's Report 1
Fan, Davidson's ... 275
Fan Dynamometer, Walker's 20
Faraday Society ...377, 379, 403, 417
Feed Motion for Machine Tools, Holroyd's ... 241
Feed Water, Treatment of, for Locomotives ... 15
File Sharpening with Sand-blast ... 81
Firebox Efficiencies in Locomotives ... 399
Firebricks, Testing of ... 138
Firebricks, Texture of...378, 403
Firing, Methods of, in Boilers ... 150
Flow of Steam, Measurement of ...363, 380
Flue Gases, Density of ... 509
Flues of Boilers, Explosions in ... 143
Food and Alcohol, Effect on Health ... 133
Forging Machines ... 171
Forgings, Drop, Heat Treatment of ...6, 71
Foundry Costs ... 295
Foundry Costs, Scovell ... 355
Foundry Cupola, Air Supply ... 2
Foundry, Electric Steel Furnace ... 284
Foundry, Importance of Tool and Storeroom ... 297
Foundry Ladle, Hyde's ... 478
Foundry Sand, Reclamation 447
Foundry Sand, Recovery of 428
Friction Clutches, Types and Uses of, W. Gass ... 342
Friction, Experiment with a Bearing ... 236
Friction of Cast Iron ... 458
Friction of Thrust Block 21
Friction, Tower & Reynold's Experiments ... 235
Fry: Hardening and Tempering of Steel ... 210
Fuel Economy at Collieries.. 87
Fuel Economy, British Association Committee's Report ...219, 238
Fuel Economy in Locomotive Boilers, Anthony ... 461
Fuel Economy Resulting from Electrical Power on the N.E. Coast ... 278
Fuel, Powdered, Mechanical Stokers for ... 257
Fuel, Powdered, Spontaneous Combustion of ...257
Fuel Purchase on Calorific Basis ... 41
Fuel Tests for Locomotives, Illinois University ... 427
Fuel Tests for Power Stations ... 394
Fuel, Use of Coal Dust 200, 256
Furnace, Air Blast, Arrangement for Efficiency ... 251
Furnace, Alldays & Onion's Tilting ... 59
Furnace, Electric, Balmforth's ... 328

PAGE

Furnace, Electric, The Gronwell Dixon 306
Furnace for Melting Brass.. 467
Furnace, Linings for ...379, 403, 417
Furnace, Oil, for Locomotives 66
Furnace, Steam heated, for Type Metal 467
Furnace Temperature in Locomotives 399
Furnace with Surface Combustion for Annealing..... 289
Furnaces at High Temperatures, Insulation of 185
Furnaces Fired with Powdered Coal for Metallurgical Work 256
Furnaces in Boilers, Manipulation of 150
Furnaces, Oil Fired, Manipulation of Burners 375
Fusible Plugs 113

G

Gadd: Powdered Coal in Metallurgical Processes ... 276
Galvanising Zinc Processes.. 269
Gardner's Oil Fuel Injector 488
Gardner's Vaporiser for Oil Engines 34
Gas Engine Cylinders, Cast Iron for, Hurst..... 458
Gas Engine Development, D. Clerk 433, 436, 469
Gas Engine Exhaust Silencer 115
Gas Engine, Power Developed in Various Countries 436
Gas Engine, Two cycle, Davidson's 268
Gas Engines at Collieries.... 88
Gas Engines, Causes of Pre-ignition 89
Gas Engines, Crossley's Starting Apparatus 195
Gas Engines, Large, Troubles with 89
Gas Engines, Utilising Waste Heat 115
Gas Explosions in Boiler Flues 143
Gas fired Boilers 141
Gas firing for Boilers ...394, 373
Gas firing of Boilers, Efficiency 141
Gas firing of Boilers, Temperature of Furnace 141
Gas Flow, Measurement of 363, 380
Gas from Coke Ovens, Power from 234
Gas Producer, Flynn and Dreffein 99
Gas Producer, Nelson's 504
Gases in Flues, Measuring Density 509
Gass, W.: Friction Clutches 342
Gauges, Limit, Principles of Use 201, 215
Gearing for Electric Locomotives 154
Gears, Helical, Elastic 63
Gemmell: Electric Power Distribution on the N.E. Coast 332
General Electric Company Helical Gears 63
German Competition, Dr. Unwin on 333
German Electrical Plant, Failures of 473
Glazebrook, Dr., on Limit Gauges 201, 215
Governing Speed, Importance in Textile Mills 293
Governor, Hartnell's Centrifugal 17
Grain Handling Appliances 347, 368
Graphite as a Lubricant 27
Graphite Lubrication for Engine Cylinders 479
Graphite Moulds for Metals and Alloys 123
Gratings, Ruling of Fine..... 156
Grease as a Lubricant 27
Griffiths: Hoisting Appliances at Ports ..317, 368, 402
Grinding Tools, Effect on Temper of High-speed Steels 340
Grinding Wheels, Trueing of, with Diamond 222
Grinding Wheels, Use of, for High-speed Steel Tools ... 341
Gronwell Dixon Electric Furnace 306
Gyroscopic Compass 412

H

Hardening and Tempering of Steel 211, 231
Hardening of Steel 163, 165
Hardening, Oil v. Water 64
Hardening Surfaces by Oxy-acetylene Flame 478
Hardness of Metals, Vickers and Smith's Testing Apparatus 74
Hardness Research Report, Institute M.E. 497
Hardness Tests 493
Harley, Malleable Iron 162
Harrington, Powdered Coal as Fuel 420
Hartnell's Centrifugal Governor 17
Hayward, Effect of Sulphur on Steel 382
Heat Insulation 135
Heat Insulation at High Temperatures 184
Heat Losses from Boiler Scale 197
Heat Losses in Locomotives from Radiation 197
Heat Transmission in Boiler Tubes 13
Heat Treatment of Aluminium-Bronze 148
Heat Treatment of Axles ... 64
Heat Treatment of Drop Forgings 6, 71
Heat Treatment of High speed Steel 5
Heat Treatment of Steel, Fry 210, 231
Heat Waste, Utilisation of, for Steam 510
Heating and Ventilating Dwelling Houses, Hanssen 391
Helical Gears, Elastic..... 63
Hibbard, H. D., Manufacture of High speed Steel... 4
Hick-Hargreaves Condenser Pump 428, 386
High pressure Electric Distribution 107, 128
High speed Steel 165
High speed Steel Analysis ... 5
High speed Steel, Effect on Temper of Grinding 340
High-speed Steel, Hibbard, Manufacture of 4, 31
High-speed Steel, Patents for 31
High-speed Steel, Theory of 31
Hitchen's Address on Trade After the War 33, 70
Hoisting Machinery for Ship's Cargoes, Sir J. Griffiths 317, 368
Holbeck's Furnace for Dust Fuel 146
Holroyd's Feed Motion for Machine Tools 241
Horse-power in Various Countries 436
Horse-power, Nominal, Board of Trade Rule..... 371
Hot-water Boiler Explosion at Manchester 373
Humidity and Ventilation... 23
Hurst, Cast iron for Engine Cylinders 458, 475
Hyde's Steel Ladle 478

I

Illumination, C. P. Steinmetz 101, 124
Illumination of Streets ... 330
Illumination of Workshops, Degree of 322
Incrustation in Boilers, A. H. Babcock 119
Incrustation in Boilers, Cost 119
Induced Draught for Boilers 150
Industrial and Scientific Research, Report of Advisory Council 223, 248, 266
Industrial Efficiency 153
Industry, Labour's Share in Division of Profits 60
Ingot Mould, Armstrong-Whitworth 377
Ingot Mould, Donner Steel Company's 227
Ingot Moulds, Talbot and James 3
Ingots, Crystallisation in, Brearley 242, 261
Ingots, Production of Sound 328
Inspector of Factories' Annual Report for 1915..... 1
Institute Marine Engineers, President's Address 198
Institute of Metals 180
Institution Civil Engineers, Presidential Address ..383, 406, 445
Institution Mechanical Engineers, Dr. Unwin's Address 333, 339
Institution M.E. Research on Hardness 493, 497
Institution of Naval Architects 444
Insulation, Electric 187
Insulation Heat at High Temperatures 184
Internal-combustion Engine Development, Dugald Clerk 433, 436, 469
Internal-combustion Engines, Air regulating Device, Cole, Marchant, and Morley 438
Iron and Steel Industries, Board of Trade Committee on 114
Iron and Steel Workers and Industrial Diseases 133
Iron, Malleable, Harley 162
Iron Prices, Jan.-June, 1916 11
Iron Prices, Official 48
Iron Production in Germany, Growth of 333

J

James's Valve for Oil Engines 414
Japanning Small Articles, 76, 78
Johannesburg Power Station Equipment 11
Johnson, Use of Graphite Lubricant for Engine Cylinders 479

K

Keadby Lifting Bridge 430
Keith's Rotary Blowers 22
Kitchen Boiler Explosion at Manchester 374

L

Labour, Output of, in Britain and America Compared 70
Labour Problems, Lanchester 486, 506
Labour, Remuneration of, G. Stoney 182
Labour Restriction of Output 194
Labour Share in Profits..33, 60, 70
Lackie, W. W., Boiler-house Design 39
Ladle for Steel Foundry, Hyde's 478
Lanchester, Economic Outlook and Labour Problem 486, 506
Lathe Chuck, Pratt and Whitney 165
Lathe Tool Holder, Taylor's 445
Lead Prices, Jan. June, 1916 11
Lifting Appliances at Ports 349, 368, 402
Lighting and Illumination 101 124
Lighting of Streets 330
Lighting of Workshops 322
Limit Gauges, Dr. Glazebrook on Use of..... .201, 215
Ljungström Bearing Lubricator 356
Ljungström Turbine 157
Ljungström Turbine Alternator for Ship Propulsion..... 160
Ljungström Turbine Alternator, Trials of 160
Lock nut, a New 392
Loco. Boilers and Fuel Economy of, Anthony..... 461
Loco. Boilers, Combustion in 461
Locomotive Boilers, Care of 127
Locomotive Boilers, Design and Maintenance 54
Locomotive Development in the United States 59
Locomotive Firebox Efficiency 397
Locomotive Firebox Temperature 399
Locomotive Fired with Dust Fuel 421
Locomotive Fuel Tests, Illinois University 427
Locomotive Fusible Plugs... 113
Locomotive Oil Furnace 66
Locomotive Radiation Losses 196
Locomotive Staybolts, Flexible 190
Locomotives, Bulging of Front Flue Sheets 28
Locomotives, Care and Management of 196
Locomotives, Compounding and Superheating, in France 251
Locomotives, Electric, Design of 501
Locomotives, Electric Gearing for 154
Locomotives, Long, Equalisation 116
Locomotives, Mikado Type, by Baldwin Company 203
Locomotives, Modernising of 67
Locomotives, Treatment of Feed-water 17
Locomotives with Mechanical Stokers in the States .. 154
Locomotives with Superheaters in the U. States... 74
Lubricants, Causes of Troubles with 27
Lubricating Oil Troubles 27
Lubricating Oils, U.S. Navy Tests of 310
Lubricating Properties of Oil 166
Lubrication, Forced 235
Lubrication of Diesel Engines 352
Lubrication of Diesel Engine Pistons 439
Lubrication of Engine Cylinders with Graphite 479
Lubrication of Friction Clutches 344
Lubrication, Theories of..... 235
Lubrication Towers and Reynold's Experiments ... 235
Lubrication with Graphite... 28
Lubrication with Grease 28
Lubricator, Automatic, Thomas's 434
Lubricator for Bearings, the Ljungström 356

PAGE

M

Machine Tool Design ... 204
Magnesium, Metallurgy of.. 83
Magnetic Units, International System of... 260
Malleable Iron ... 162
Management of Works, Organisation of ...316, 336
Manchester Association of Engineers, Presidential Address, F. W. Reed.. ... 301
Manchester Heating Boiler Explosion ... 374
Marine Engineers, Institute of, Presidential Address ... 198
Marine Engines, Development of ... 200
Marine Oil Engine, Future of, Wentworth ... 361
Martell Scholarship in Naval Architecture ... 422
Matthewson Sand blast Apparatus ... 81
Mayari Steel ... 138
Mazda Lamp ... 125
Measurement of Steam Flow in Pipes ... 365
Measurements, Fine, in Dividing Engines ... 156
Mechanical and Chimney Draught ... 450
Mechanical Engineers' Institution, Dr. Unwin's Address ...333, 339
Mechanical Stokers for Powdered Fuel ... 257
Mechanical Stokers on Locomotives in the States ... 154
Mellor, Dr., Refractory Materials for Furnaces ... 397, 403
Melting Metals with Steam Heat ... 467
Mertz on Electric Power Distribution ...271, 286
Metal Cutting Tools, Design and Grinding of, W. Cole 230
Metal Prices, Jan. June, 1916 11
Metal Waste in Engineering Works ... 431
Metals, Rare, Metallurgy of 83
Metals, Size of Grains in ... 46
Metals, Thermo-electric Properties of ... 93
Metallurgy, Powdered Coal Furnaces for ... 256
Meter for Water, Electrically Operated ... 76
Meter, Pump for Measuring Liquids ... 496
Metric System and Screw Threads ... 393
Minute Measurements of Angles ... 156
Molybdenum, Uses of ... 451
Morison's Air Extractor for Condensers ... 325
Motor car Running Test ... 412
Moulds, Permanent, of Graphite for Castings ... 123
Multitubular Boilers, Expansion of ... 468

N

National Gas Engine Company Gas Engine Improvements ... 280
National Physical Laboratory, Inadequate Support 181
Naval Engineering Developments, Dinger, U.S.N. ... 409, 387
Navy Zinc bronze, Strength 11
Nelson's Gas Producer ... 504
Nernst Lamp ... 125
Nesbit, Testing of Fire bricks ... 138
Nickel chromium Steel ... 137
Nominal Horse-power, Board of Trade Rule ... 371
Non-conducting Coverings for Boilers and Steam Pipes ... 135
Non-conductors for High Temperatures ... 184
Nut lock, a New ... 392

PAGE

O

Oil and Gas Engine Development, D. Clerk...433, 436, 469
Oil Burner, Turconi's ... 177
Oil Burners, Safety in Use.. 375
Oil Engine Exhaust Silencers ... 115
Oil Engine, James's Valve... 414
Oil Engine, Marine, Future of, Wentworth ... 361
Oil Engine, Petter, Feed Pump ... 406
Oil Engine, Petter's Two-cycle ... 134
Oil Engine, Rotary Valve for ... 286
Oil Engine, Six-cylinder Rotary, Ruston & Chorlton ... 248
Oil Engine, Two-cycle, Walker's ... 304
Oil Engines and Steam Engines in Combination ... 35
Oil Engines, Gardner's Vaporiser ... 34
Oil Engines, Heavy, S. Daugherty ...349, 368
Oil Engines Utilising Waste Heat ... 115
Oil fired Cupola for Foundry ... 155
Oil for Tempering Steel ... 211
Oil Fuel Burning Tests, U.S. Navy ... 335
Oil fuel Injector, Gardner's.. 488
Oil Furnace for Locomotive 66
Oil in Boilers, Overheating Troubles Caused by ... 7
Oil, Lubricating, Properties 166
Oil Engines, Crossley's Starting Apparatus ... 195
Oil Lubricating Troubles, Causes of ... 27
Oil motored Traction Engines, Test of ...454, 456
Oil Production, World's ... 349
Oil Viscosity, Measurement 166
Oil v. Water Hardening ... 64
Oils, Lubricating, U.S. Navy Tests of ... 310
Open hearth Furnaces, Repair of, While in Work... 485
Ore, Appliances for Handling 369
Organisation for Sales ... 357
Organisation of Engineering Works...316, 336, 357
Organisation of Trade After the War ... 453
Orrok, Design of Surface Condensers ... 465
Output and Working Hours, Dr. Vernon ... 233
Output of British and American Workmen Compared ... 70
Output, Restriction of, by Trades Unions ... 193
Overheating of Boilers from Grease and Floury Deposit 7
Oxy-acetylene Flame for Case Hardening ... 478

P

Painting by Dipping and Spraying ... 76
Paint-spraying Apparatus... 76
Paterson Water-softening Apparatus ... 80
Patterns, Standards, Colours to Indicate Machining ... 314
Petroleum Output of U.S... 349
Petroleum, World's Output 349
Petter Feed Pump for Oil Engines ... 406
Petter's Two-cycle Oil Engine ... 134
Piece Work in Engineering Shops ... 182
Pipes, Corrosion of, Speller 502
Pipes, Steam, for Boilers, Defects in ... 9
Piston of Diesel Engines, Lubrication of ... 139
Pistons of Diesel Engines, Fractures of ... 175
Planing Machine, Stirk's Reversing Gear ... 194
Platinum ... 427
Porter-Geoffrey Diesel Engines and Steam Engines in Combination ... 35
Powdered Coal as a Fuel ... 420, 429
Powdered Coal Dust, Holbeck's Furnace for ... 146
Powdered Coal in Metallurgical Processes, Gadd, 256, 276
Power Cost, Electricity v. Steam, Stromeyer ... 400
Power Developed in Various Countries ... 436
Power Distribution by Electricity, Mertz ...271, 286
Power, Electric Distribution on N.E. Coast ... 278
Power Plant at Collieries... 87
Power Plant, Large, Efficiencies of ... 42
Power station Equipment at Johannesburg ... 14
Power Transmission in Textile Mills, Charnock ... 293
Pratt & Whitney Lathe Chuck ... 165
Prices, Official, for Coke, Iron, and Steel ... 49
Prices of Metals, Jan. to June, 1916 ... 11
Producer-gas for Boilers and By-products ... 394
Producer, Gas, Flinn and Dreffein ... 99
Producer, Gas, Nelson's ... 504
Production of British and American Workmen Compared ... 70
Profit Sharing ... 194
Profit-sharing in Industry, Lanchester ... 481
Profits, Labour's Share ...33, 60
Propeller Shaft Thrust Block 21
Pump, Davy's, Compound Condensing ... 495
Pump for Condensers, Hick, Hargreaves ... 428
Pump, Rotary, Selson Engineering Company ... 180
Pumps for Measuring Liquids ... 496
Pumps, Turbine, Rufener and Wiesengrund ... 98

R

Radiation Losses from Locomotive ... 196
Radiation, Non conducting Coverings to Prevent ... 135
Rail Fractures, Some Causes of ... 51
Railway and Shipping Freights ... 93
Reavell & Jones' Air Compressor ... 219
Reavell's Two stage Air Compressor ... 137
Reducing Valve, Bailey's ... 191
Reed, F. W., Presidential Address to Manchester Association of Engineers.. 301
Refractory Materials ...377, 379, 403, 417
Report of Inspector of Factories ... 1
Research in Engineering, G. Stoney ... 182
Research in Science ... 434
Research, Scientific and Industrial, Report of Advisory Council ...223, 248, 266
Research, Scientific, Value.. 173
Retaining Walls, Earth Pressure ... 491
Richardson on Sand-blasting Apparatus ... 81
Riveted Joints, Partition of Loads, C. Batho ... 455
Rivet Steel, Effect of Sulphur ... 145
Robinson's Vaporiser for Oil Engines ... 395
Rogers, Captain, U.S.N., on Submarine Design ... 488
Rolling Mill Improvements.. 419
Rolling Mills, Direct-current Motors for ... 481
Rolling Steel, Power Required for, Sames ... 58
Rotary Blower, Keith's ... 22
Rotary Oil Engine, Ruston and Chorlton's ... 248
Rotary Valve for Oil Engine 284
Rowland's Grating, Ruling.. 156
Ruston & Chorlton Six-cylinder Rotary Oil Engine.. 248

S

Safety Valves, Defects in... 8
Safety Valves for Kitchen and Heating Boilers ... 374
Safety Valves, G. H. Clark... 101
Sames, Power Required to Roll Steel ... 58
Sandblast Cleaning of Castings ... 82
Sandblast Sharpening of Files ... 81
Sandblasting, and Apparatus for ... 81
Sand for Foundry, Reclamation of ... 447
Sand for Foundry, Recovery 428
Scale in Boilers, Heat Losses from ... 197
Science and Industry, Official Report on ... 49
Science and Research Work 173, 181
Science, Importance in Industry ... 73
Science, its Value in Industry ...173, 181
Science, Popular Lectures... 304
Scientific and Industrial Research Committee ... 74
Scientific and Industrial Research, Report of Advisory Council ...223, 248
Scientific Education of Engineers ... 20
Scientific Research ... 434
Scleroscope ... 497
Screw Gauges for Limit Work ... 201
Screw Gauges, Standardisation of ...201, 215
Screw Propeller, The Mystery of, Dyson ... 90
Screw Threads and the Metric System ... 393
Screw Threads, Misfits in... 66
Selling Organisation ... 357
Selson Engineering Company's Rotary Pump ... 180
Shaft cleaning Device ... 30
Shanghai Electrical Plant, Failure of ... 473
Shells, Painting of ... 79
Sherardising Zinc Process ...269
Ship Engine Repairs under Difficulties ... 199
Ships, Electric Propulsion... 157
Ships, Electric Propulsion of 409
Shipbuilding in 1915-16, Lloyd's Returns ... 374
Shipping Freights ... 93
Silicon, Effect in Cast Iron.. 477
Similitude in Engineering Design ... 280
Slag Blastfurnace, Use of... 209
Sloan on Fuel Economy from Electric Power Schemes on N.E. Coast ... 278
Smith, E. A., Metallurgy and Applications of Zinc.. 227, 246, 269
Smith, P. H., Crankshaft Failures in Diesel Engines ...53, 56
Smith & Vicker's Hardness Testing Apparatus ... 74
Smoke Tubes in Boilers, Re-crystallisation of ... 100
Soot as a Non-conductor of Heat ... 197
Speed Regulation in Textile Mills, Charnock ... 293
Speller, Corrosion of Pipes... 502
Spelter, Grading of ... 149
Spelter, Impurities in ... 26

PAGE
Spelter Industry, Development ... 218
Spontaneous Combustion of Powdered Coal ... 257
Spraying of Paint ... 76
Springs, Manufacture and Design ... 115, 448
Standardisation in Engineering ... 206
Stanton, Similitude in Engineering Design ... 280
Staybolts, Flexible, for Locomotives ... 190
Steam Engine Tests ... 413
Steam Engine, the Uniflow, Todd, the Inventor ... 94
Steam Engine, Uniflow Development of, Trinks ... 366
Steam Engines and Diesel Engines in Combination... 35
Steam Engines, Average Coal Consumption ... 354
Steam Engines, Coal Consumption ... 401
Steam Engines, Economy, *v.* Diesel Engines ... 350
Steam Flow, Measurement of, Bailey ... 363, 380
Steam Pipes and Water Hammer ... 10
Steam Pipes, Non-conducting Coverings ... 135
Steam Pipes of Boilers, Defects in ... 9
Steam Trap, Baker's ... 214
Steel Alloys for Structural Purposes ... 89
Steel, Cast, Harley ... 162
Steel Castings, Gating of... 345
Steel Castings, Use of Titanium ... 325
Steel, Crystallisation of ... 190
Steel Driving Belts ... 106
Steel Effect of Alumina... 298
Steel, Effect of Sulphur, Hayward ... 382
Steel, Eutectoid, Hardening and Tempering of ... 231
Steel for Rivets, Effect of Sulphur ... 145
Steel Foundry, Hyde's Ladle ... 478
Steel Furnace, Electric, for Foundry ... 284
Steel Furnaces, Open-hearth, Repair of While in Work ... 485
Steel, Hardening and Tempering ... 211
Steel, Hardening of ... 163, 165
Steel Heat Treatment, Fry.. 211
Steel, High speed ... 165
Steel, High-speed, Analysis.. 5
Steel, High-speed, Effect of Cobalt, Chromium, and Vanadium ... 5
Steel, High-speed, Heat Treatment ... 3
Steel, High-speed, Manufacture of, Hibbard ... 4, 31
Steel, High-speed, Patents... 31
Steel, High-speed, Theory of 31
Steel, High-speed Tools, Effect of Grinding on Temper ... 340
Steel Ingot Mould, Armstrong-Whitworth ... 377
Steel Ingots, Crystallisation in, Brearley ... 242, 261
Steel Ingots, Hot Top for, Donner Steel Company... 227
Steel Ingots, Production of Sound ... 328
Steel Ingots, Talbot and James Moulds for... 3
Steel Manufacture, Rise and Decline of Bessemer Process ... 213
Steel, Nickel-chromium ... 137
Steel, Power Required to Roll, Sames ... 58
Steel Prices, Official..., 48
Steel Production in Germany, Growth of ... 333
Steel Rolling Mills, D.C. Motors for ... 481
Steel Scrap, New Process for Melting ... 240
Steel Sheets, Corrosion of... 320
Steel Specifications for the Foundry ... 288
Steels, Analysis of Various... 90
Steels, Tungsten ... 123
Steinmetz, Light and Illumination ... 124
Stirk Reversing Gear for Planing Machines ... 194
Stone Dusting in Mines, Efficiency of ... 237
Stoney, Gerald, Importance of Research Work ... 182
Stoney, Gerald, Industrial Efficiency ... 181
Stratton, D.C. Motors for Rolling Mills ... 481
Stromeyer, Economy of Fuel 400
Structural Alloy Steels ... 89
Stumpf Engine, Working Results ... 366
Submarine Design, Rogers, U.S.N. ... 488
Sulphur, Effect on Steel... 382
Sulzer Bros.' Cylinders for Single-acting Oil Engines.. 366
Superheaters and Steam Pipes, Growth of Cast-iron ... 475
Superheaters for Locomotives in the States ... 75
Superheating and Compounding on French Locomotives ... 251
Surface Combustion for Annealing Furnace ... 289
Surface Condensers, Design of, Orrok ... 465
Swasey on Graduating Dividing Engines ... 156

T

Talbot & James, Moulds for Steel Ingots ... 3
Taylor's Lathe Tool Holder.. 445
Technical Education, Value.. 173
Temperature, Insulation at High ... 184
Temperature of Boiler Plates ... 13
Temperature of Fuel Bed in Locomotive Firebox... 399
Tests of Aluminium-Bronze.. 148
Textile Mills, Uniform Driving in, Charnock ... 293
Thermo electric Properties of Metals ... 92
Thomas's Automatic Lubricator ... 434
Thompson, B., on Boiler Problems and Their Solution ... 7
Thrust Block, Design of... 21
Tilghman's Sand-blast Apparatus ... 81
Tin, Analysis of Various Brands ... 161
Tin Composition and Uses of 161
Tin for Fusible Plugs ... 113
Tin Prices, Jan.-June, 1916.. 11
Titanium, Use in Steel Castings ... 325
Todd, Inventor of Uniflow Engine ... 94
Tool Design ... 205
Tool Holder for Lathe, Taylor's ... 445
Townley Shaft-cleaning Device ... 30
Traction Engines with Oil Motors, Tests of ... 454
Trade After the War ... 33
Trade, British Promotion of 491
Trade, Iron and Steel, After the War ... 114
Trade Organisation After the War ... 453, 456
Trades Union Interference with Output ... 193
Trades Union Rules and Restriction of Output ... 302
Trades Unions Regulations After the War ... 153
Transformers, Air-cooled ... 189
Transport Methods with Ships' Cargoes at Ports, Sir J. Griffiths ... 347, 368
Trinks, Development of Uniflow Engine ... 366
Tubes for Evaporators, Watson & Billetops ... 171
Tubes in Boilers, Crystallisation of, White and Wood ... 100
Tungsten, Molybdenum Alloys ... 123
Tungsten Ores in Malay States ... 441
Turbine and Electric Motor, Combined Plant for Marine Propulsion, Westinghouse ... 85
Turbine, Bleeder or Extraction Type ... 85
Turbine, Compound, for 30,000 kw., Test of ... 175
Turbine Performances in U.S. Warships ... 388
Turbine Pump, Rufener and Wiesengrund ... 98
Turbine Tests, Correction of 290
Turbine, the Lungström ... 157
Turbine Vessels in U.S. Navy 387
Turbines at Collieries ... 88
Turbines, Gearing *v.* Electric Drive, for Ships ... 409
Turbines *v.* Diesel Engines, for Mine-power Plants ... 186
Turbo alternator, Test of a 3,000 kw. ... 15
Turbo alternators, Cooling... 14
Turbo electric Propulsion of Ships ... 157
Turner, Thermal Reactions in Cast Iron ... 389

U

Uniflow Engine Development, Trinks ... 366
Uniflow Engine, Origin of... 94
Unwin, Dr., Address to Institute M.E. on German Competition ... 333, 339

V

Valve, Rotary, for Oil Engines ... 286
Valves for Oil Engines, James' ... 414
Valves, Safety, G. H. Clark 101
Valves with Flexible Seatings, Gibson & Bevis ... 147
Vanadium Effect on High-speed Steel ... 5
Vanadium, Use of, in Steel.. 327
Vaporiser for Oil Engines, Gardner's ... 34
Vaporiser, Robinson's ... 395
Velocity of Steam in Condenser Tubes ... 466
Ventilation and Carbonic Acid Content ... 24
Ventilation and Heating of Dwelling-houses ... 391
Ventilation and Humidity... 23
Ventilation, Requirements and Test Methods, Hill ... 23
Ventilation of Turbo-alternators ... 14
Vernon, Dr., on Working Hours and Output ... 233
Vickers' Hardness Testing Apparatus ... 74
Vickers' Oxy acetylene Surface Hardening Process... 478
Viscosity, Measurement of... 166
Viscosity of Oil ... 166

W

Wages in Engineering Works, Piece and Bonus Systems, G. Stoney 182
Walker's Fan Dynamometer 20
Walker Two-cycle Oil Engine 304
Walls, Retaining, Earth Pressure on ... 191
Wardle's Die-casting Apparatus ... 261
Waste Heat in Gas and Oil Engines ... 115
Waste Heat, Utilisation of, for Power on N.E. Coast, Sloan ... 278
Waste Heat, Utilisation of, for Steam ... 510
Waste Metal in Engineering Works, Disposal of... 431
Water feed for Locomotive Boilers, Treatment of ... 17
Water hammer in Steam Pipes ... 10
Water Meter, Electrical... 76
Water Softening for Locomotive Boilers ... 18
Water softening, Paterson Apparatus ... 80
Water Treatment in Boilers 119
Water tube Boiler, Deighton's ... 458
Watkinson, Prof., Starting Diesel Engines with Low Compression ... 299
Watson & Billetop Heat transmitting Tubes ... 171
Webster & Bennett Boring Mill ... 206
Webster & Bennett Control for Boring Mills... 379
Weights and Measures, Metric System ... 393
Wentworth, Future of Marine Oil Engine ... 361
West, R. D., Gating of Steel Castings ... 345
Westinghouse Combined Turbine and Electric Motor for Ship Propulsion 85
Wheels, Helical, Elastic ... 63
White, Condenser Tube Troubles ... 84
Willans' Condenser, Test of 354
Wilson, L. F., Treatment of Feed water for Locomotives ... 17
Wolfram Ores in Malay States ... 441
Working Hours and Output, Dr. Vernon ... 233
Workmen, Output of, in Britain and U. States Compared ... 70
Works Management ... 316, 336
Workshops, Illumination of.. 322
World, Horse-power in... 436
World's Output of Petroleum ... 349
Wrought Iron, Effect of Blastfurnace Gas ... 255

Z

Zinc, Adulteration of ... 149
Zinc bronze, Heat Treatment ... 10
Zinc bronze, Standard Test and Strength of ... 10
Zinc, Effect of Cadmium... 218, 241
Zinc, Effect of Cadmium on 26
Zinc, Galvanising ... 269
Zinc, Grading and Use of... 149
Zinc, Industrial Applications of ... 269
Zinc Industry, Development 218
Zinc, Metallurgy of, E. A. Smith ... 227, 246
Zinc Prices, Jan. June ... 11
Zinc, Sherardising ... 269
Zinc (Spelter) Impurities... 26

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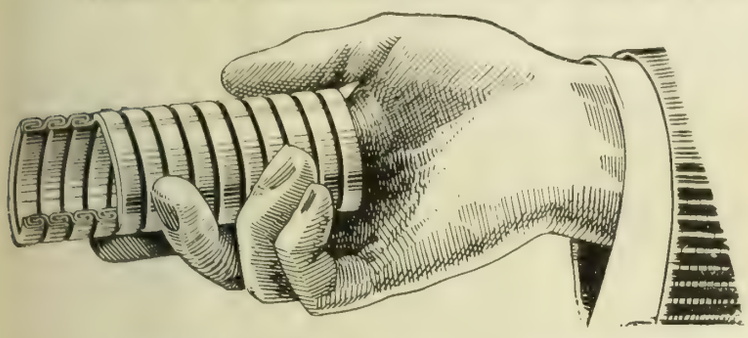

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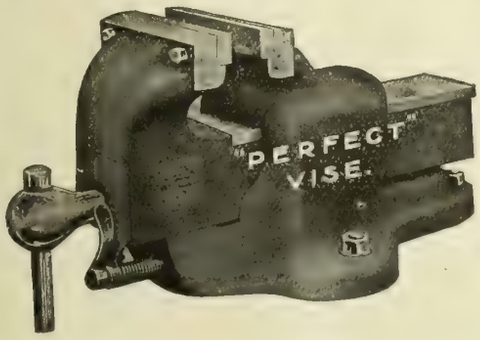

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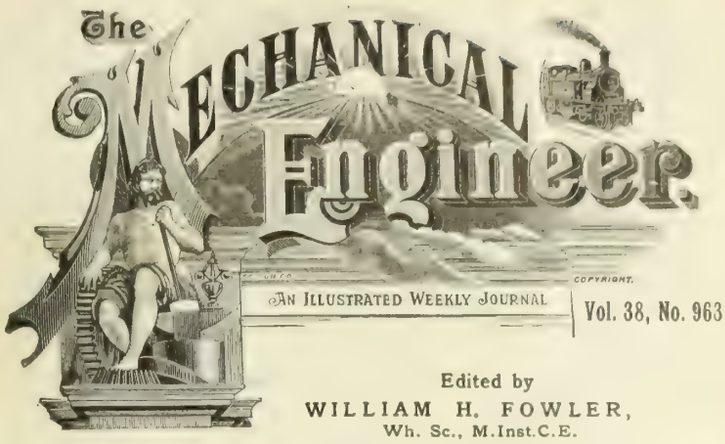

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Annual Report of the Chief Inspector of Factories.

THE annual report of Mr. Whitelegge, the Chief Inspector of Factories, is a striking reflex of war conditions. Its bulk—it only amounts to 15 pages all told, as compared with 133 pages last year and 270 pages of a couple of years ago—might, at first glance, be taken as a measure of the scarcity of paper, but as a matter of fact the attention of the staff of inspectors has been mainly occupied with the access of special duties which have fallen on the Factory Department of the Home Office in connection with the dilution of labour necessitated by the transference of so large a section to the army, and the report deals only this year with this section of its duties. The task was undertaken jointly with the Board of Trade at the request of the Army Council, and the principal difficulty, as we know, arose from the opposition raised by the trade unions to the suspension of their rules and customs. Guarantees were demanded that those who left the ranks of labour to join the Forces should have their places kept open, that at the end of the war there should be a return to former conditions, and in the meantime there should be a fair settlement of wage questions affecting women or other labour called in to take the place of men transferred. In most of the trades concerned there was little difficulty in arriving at agreements between the official trade union representatives and the other parties concerned. There have, it is true, been some very regrettable exceptions to this, especially in the engineering trades, but the majority of these have arisen out of the action of sectional bodies of workmen instigated by "shop delegates," as in the case of the strike which occurred at Vickers' works at Barrow during the past week, where 5,000 engineers refused to recognise the Joint Trade Committee, representing the various trade unions, and elected a body of "shop delegates," who took up the position that there should be no dilution of labour, and decided by a majority to strike, notwithstanding that

their action was repudiated by the Executive Council of the Amalgamated Society. To the satisfaction of every true citizen the Government took strong action. All picketing was forbidden, public houses were closed, the recalcitrants were warned that failure to resume work would be followed by proceedings under the Defence of the Realm Act against the instigators and under the Munitions of War Act against the others, with the result that the strike at once collapsed. We trust that in the interest of the large majority of loyal trade unionists, as well as of their official representatives, any further similar action of the extremists will be treated just as summarily. Too much regard has been paid to their opinions, and to allow them to interfere with our national efforts in the present crisis is to trifle with treason. The various agreements which were made have on the whole been faithfully observed, and arising out of them special orders have been issued by the Home Office to enable certain trades to meet the demands made upon them, principally in connection with overtime. In the industries associated with the manufacture of munitions continuous night and day labour was for some time instituted. It has been found, however, that such effort was incapable of permanent continuance, and that from the point of view of efficiency a brief weekly rest was desirable. Apart from the ill effects which follow from long-continued spells of work without the customary Sunday rest, it often resulted in loss of time on other days of the week on the part of some men, and consequent disorganisation of the rest, and at present a weekly Sunday rest is more or less secured to all workers. Where work is not done in shifts it is far preferable to work a moderate amount of overtime during the week and allow a complete break on the Sunday, rather than work continuously from day to day. The working of shifts is not always so easy as seems on paper. There is much, of course, to be said for it, since it keeps all available machinery continuously employed, but shortage of skilled labour makes its universal adoption impossible. In some cases eight-hour shifts are in operation, but they are mainly confined to work on which female labour is employed, and even in their case, owing to labour scarcity, these have to fit in with twelve-hour shifts of the male tool setters, and it is for this reason that employers generally in the engineering trades have been driven to choose a double rather than a treble system of shifts. There has been no set scheme of hours where the extra work is limited to overtime, the systems adopted varying with localities, and being governed by the custom of the district. In some the overtime is spread evenly over all the days of the week. In others there is a preference for extra work on two or three days with normal hours on the others. Again, in some districts the workers desire to stop as early as possible, and prefer a long spell of work in the afternoon without an interval for the evening meal, rather than to have such an interval and work later. While the desire to break off earlier is laudable, experience shows long spells are not conducive to good output, and so far, therefore, as protected labour is concerned, the Department have limited the unbroken spell to 5 hours in textile and 5½ hours in non textiles. So far it has been impossible to obtain precise data showing the actual effect of increased hours of production. The amount of machinery employed, the number of hands engaged, and the divergent skill brought to bear make this difficult. It is scarcely to be wondered at that divergent views are held. The general opinion seems to be, however, that reasonable overtime does yield increased output, though not in full proportion to the hours worked. The great increase in machinery, longer hours, and the introduction of female labour, have raised many new problems in connection with fencing, ventilation, and sanitation, and owing to the present abnormal pressure many of these are in a state of flux. One satisfactory feature, however, of which mention should be made, is the great advance in what is known as welfare work, *i.e.*, the provision of canteens, messroom accommodation, and arrangements for dealing with cases of sickness and injury. In most of the large works special lady supervisors have been appointed to look after the general welfare of the women, and assist in the maintenance of proper order and discipline. These officers have proved a great success, and their further introduction is now being encouraged. In small works the special officers are usually replaced by a superior forewoman, but it is made a condition on all Orders allowing night work for women, that suitable provision shall be provided. The need for adequate arrangements for meals is obvious, especially where long hours or night shifts are worked, and the benefits accruing from these have been so well proved that they will doubtless be continued when normal conditions are restored. Whilst trade as a whole is in a state of boom and unemployment is probably at a lower level than it has ever been before, there are a few trades which have been rather badly hit. The building trade, for instance, in most districts, and the industries dependent upon it, such as joinery, brick and tile making, &c. The printing trade, too, is a striking exception, owing to restriction partly on paper and colours, and secondly, the absence of all demands for catalogues and trade literature, owing to works being employed on Government work. This, however, has not affected the ranks of labour, owing to the tempting openings in other directions and the demands for men in the army. No one, in fact, need now complain that he cannot obtain work. There is enough for everyone willing to undertake it.

AIR SUPPLY FOR CUPOLAS.

IN a paper on "The Relation of Air Supply to Cupola Blowing," recently presented at a meeting of the Newark Foundrymen's Association, Mr. J. A. Shorey stated that the conservation of the heat value of the fuel was directly dependent on a uniform rate of melting, which, in turn, depended on the supply of a definite weight of oxygen delivered to the cupola at a definite and uniform rate, covering not only the period of melting, but each instant of the entire period. It had generally been accepted that 30,000 cub. ft. of displaced air should be allowed for every ton of iron under ordinary conditions of melting. From computation it had been assumed that 150 cub. ft. of air was required to burn 1lb. of carbon to CO_2, and in ordinary practice 1lb. of coke was sufficient to melt 10lbs. of iron. This assumption was made on the basis that coke was pure carbon. Commercial coke analyses varied widely, but a fair average of carbon might be assumed to lie between 85 and 90 per cent., which reduced the air requirement in this proportion. In actual practice 24,000 cub. ft. of free air had been found necessary for the melting of a ton of iron under the assumed ratio of 10 to 1. The weight of the oxygen contained in a cubic foot of air under normal weather conditions varied widely, as the temperature varied. Again, the weight of a cubic foot of air varied directly as the barometric or absolute pressure. If the percentages of these two variables were cumulative, that is, with a low barometer and high temperature, the oxygen content by weight of a cubic foot of air might vary widely. It must be realised that imperfect, irregular combustion not only increased the coke ratio, and therefore the cost of coke, but it resulted in increased losses of the iron itself. Tests had indicated a variable ranging from 5 to 10 per cent. of the total iron melted. In other words, in operating a cupola, while the coke was carefully weighed, likewise the iron, the weight of the air, and rate at which it was supplied, which were of equal importance, were left to the judgment of the operator, or to the exigencies of handling the iron, rather than to the over-all economy of melting.

BOOK REVIEWS.

Heat Treatment of Tool Steels : An Illustrated Description of the Physical Changes and Properties Induced in Tool Steel by Heating and Cooling Operations. By Harry Brearley. Second edition. London: Longmans, Green, & Co. 9in. by 6in. 223 pp. Price 10s. 6d. net.

The author will be known to some of our readers in his connection with a valuable paper he read about two years ago on the heat treatment of structural steel before the Manchester Association of Engineers. The volume under notice deals with a similar phase in the treatment of steel objects and tools for various purposes in the workshop, and is written with a view of practical utility to the trained artisan and foreman, as well as to the merchant and manufacturer, whose officials have frequently to meet and deal with complaints that involve knowledge they have seldom a chance of acquiring in the daily routine of their business. With increasing complexity of products and physical properties, it is to the latter especially that the consumer naturally turns for information and instruction regarding treatment or troubles in the working of steel. In earlier days, when classification of steel was not so important and selection of quality depended largely on visual inspection of fracture of the small ingots of tool steel, the combined experience of maker and user sufficed very largely to adjust products and needs. Chemical, physical, and microscopical tests have, however, now raised the question of steel selection and treatment for a particular purpose, generally defined as "temper," to a more or less exact science, and it behoves all responsible for the manipulation or treatment of steels for special purposes to possess some intelligent appreciation of the reasons underlying the various processes. Such knowledge it is the author's purpose to convey. He truly observes that the ultimate value of a tool often depends as much on the manner in which it is worked into its finished state as on the material from which it is made. Such skill and knowledge must be taken into account in any case, and if it cannot be relied upon it means almost invariably that softer steels are introduced, and this in its turn means dissatisfaction of the tool user. A careful study of this book should do much to avoid the troubles that come about in this way and guide the tool maker to locate and avoid many that not infrequently vex him, as well as those who rely upon his skill. Such study will at least serve to show that the efficiency of tools is not altogether in the hands of the steel maker, and that not all broken or defective tools can be justly ascribed to bad steel. The work is at once both practical and scientific, and no steel maker or user need be afraid of failing to comprehend the author's meaning.

* * *

Centrifugal Pumps and Suction Dredgers. By E. W. Sargeant. With 180 illustrations. London: Chas. Griffin and Co., Ltd. 9in. by 6½in. 188 pp. Price 10s. 6d. net.

This book is decidedly more descriptive than analytical; practical rather than theoretical; not that it appeals to a narrower audience on that account. Its numerous examples from actual working, and the problems to which the author addresses himself, are precisely those which the draughtsman or user will oftenest meet with in the ordinary course of things, and on which therefore the book will prove most useful. The aspect of difficulties depends a great deal on the point of view, and the student when he leaves the college for the workshop or the field finds that class text books often leave him short of the information he most sorely needs, and it is in this respect that the book will probably be most valued. The author writes with the familiarity that comes of a long practical experience of his subject and an absence of the higher mathematics that shows how little of it is needed in the bulk of the problems the working engineer is daily called upon to solve.

* * *

Large Electric Power Stations : Their Design and Construction. By Dr. G. Klingenberg. English translation; with 180 illustrations. London: Crosby Lockwood & Son. 10in. by 8in. 260 pp., with 7 large folding plates. Price 25s. net.

A publisher's note announces that this translation was in type some months before the war, but that it has since been subject to revision by an English engineer and, we presume, therefore brought reasonably up to date. The subject is one which in its entirety can only appeal to a comparatively small class, though the scale on which power is produced in central stations naturally exalts many questions, which are neglected or relegated to the background in small units, to positions of supreme importance. The author treats the subject in its broad commercial aspects, and naturally many of the illustrations are taken from continental practice, though the power stations on the Rand are also largely drawn upon, and provide excellent examples. The working out of these various schemes are all carefully described and submitted to comparative analysis. To the select class of engineers responsible for the designing of large central power stations the work contains a great deal of information which it would be difficult to find except by prolonged search through the proceedings of societies, and probably then not in so convenient a form, and to this class the volume will prove useful.

MOULDS FOR CASTING IRON AND STEEL INGOTS.

THE accompanying illustrations show several designs of composite moulds recently patented by Mr. Benjamin Talbot, County Bank Chambers, Middlesbrough, and Mr. John E. James. To prevent the formation of piping and blow-holes in ingots, deoxidisers, such as aluminium or ferro-silicon, are sometimes added to the metal while in the liquid state, and before or whilst it is cast into the mould. When such deoxidisers are used, blow-holes are largely avoided, but the piping or central cavity tends to increase. To get rid of the central cavity in the body of the ingot, it is not unusual to have the top of the mould formed of fire-clay, silica, slag-wool, asbestos, infusorial earth, coke, graphite, or other refractory material which is a slower conductor of heat than the rest of the metal mould. In such cases the heat at the top of the ingot is not so rapidly conducted away and the interior of the top of the ingot remains liquid for a longer period, and flows down and fills the bottom of the cavity. Other methods include the employment around the top of the mould of an annular space or chamber, which is made of iron in one or more parts, and placed in or on the mould (but the inner face of which is preferably of refractory material) into which

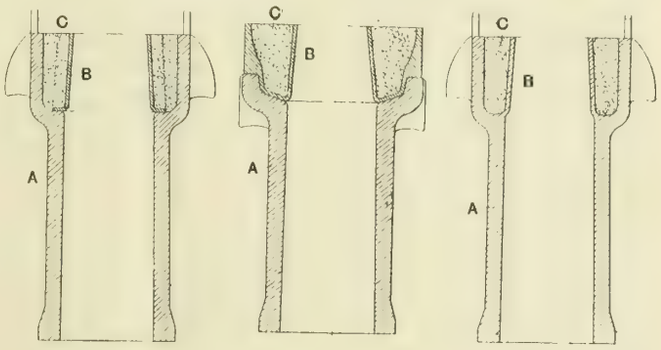

FIG. 1. FIG. 2. FIG. 3.
MOULDS FOR CASTING IRON AND STEEL INGOTS.

is poured liquid slag or other heated body such as sand, liquid slag being also run in above the top of the ingot, or to have part of the top of the mould contain an internal cavity so as to form a more or less non-conducting wall. The moulds illustrated are of the type having a chamber at the top packed with refractory material. Fig. 1 shows a sectional elevation of a mould, the head of which in the ordinary course would be raised when the mould is stripped from the ingot and rising with the mould; Fig. 2 shows a head which would generally be removed prior to stripping the ingot; and Fig. 3 shows a mould in which the inner face is carried up so as to leave a recess between it and the outer portion of the mould which is filled with non-conducting material. Whichever form is employed the object is the same, namely, to retain the heat in the upper portion of the ingot so that the more fluid material therein will flow down and fill the main portion of the cavity as the ingot solidifies, and also give a smooth surface to the ingot the same as is obtained upon its lower portion. In all of the illustrations A represents the main body of the mould, B the metal forming the inner face of the head, and C the refractory material. Where the head is removable it may be either formed in a single piece or in sections bolted or otherwise secured together.

THE MANUFACTURE AND USE OF HIGH-SPEED STEEL.*

BY HENRY D. HIBBARD.

HIGH-SPEED tool steels have in the past fifteen years worked a remarkable revolution in the machine-shop business of the whole world, affording largely increased outputs and commensurate lower costs. As a consequence they are now being used very generally and in some shops almost exclusively for machining iron and steel as well as some other metals by cutting operations by machine tools. The revolutionary feature wherein tools made of these steels differ from and exceed in service the tools formerly used is their ability to maintain a sharp strong cutting edge while heated to a temperature far above that which would at once destroy the cutting ability of a simple steel tool. Because of this property a tool made of high-speed tool steel can be made to cut continuously at speeds three to five times as great as that practicable with other tools, and when, as the result of the friction of the chip on the tool, it may be red-hot at the point on top where the chip rubs hardest, and the chip itself may, by its friction on the tool and the internal work done on it by upsetting it, be heated to a blue heat of 296° C. (565° Fah.), or even hotter to perhaps 340° C. (644° Fah.).

This property of red-hardness or ability to retain hardness at a red heat may be imparted to steels of suitable composition, comprising chromium and tungsten, by a unique heat treatment to which they may be subjected. This treatment, described later, was introduced by F. W. Taylor and Maunsel White at the works of the Bethlehem Steel Company in 1899, and tools so treated were shown at the Paris Exposition in 1900, where they naturally created a great sensation among those familiar with the machining of metals. In the United States in 1913 about 7,000 tons of high-speed or rapid tool steels was made by some 15 makers, that output requiring about 8,000 tons of ingots.

Manufacture of High-speed Tool Steel.—High-speed tool steels are all made by the crucible or electric-furnace process. Except at one works the crucibles or pots are made of graphite. The average life of the crucibles or pots varies in different works from six to nine melts. Some makers use clay-lined graphite pots in melting this steel to prevent or hinder the absorption of carbon from the pot. The clay lining is only $\frac{1}{8}$in. to $\frac{3}{16}$in. thick and is sometimes cut through on the second or third melt; in that event the molten steel may absorb too much carbon. Other makers use a graphite pot twice—first for melting other kinds of steel and then for rapid steel when the inner surface of the pot is somewhat slagged over, because of which the absorption of carbon is much less than when the pot was new.

The large producers use gas-fired melting furnaces for heating the pots, which are charged into the furnace at the top. Each melting hole contains six pots, and each pot takes a charge of 90lbs. or 100lbs. The charge is melted and then "killed" in the usual way by being held 30 to 40 minutes. Such procedure, together with the presence of the large amount of alloy, regularly gives sound steel. If run continuously a furnaceful of pots will be melted about every four hours.

In packing a pot with a charge for high-speed steel the tungsten must be placed on top of the charge—as with simple tungsten steel—to guard as far as possible against the tendency of the tungsten to settle because of its high specific gravity. That tendency seems to be less with the rapid steels than with the simple tungsten steels. Whether the chromium of the former influences or hinders the settling of the tungsten is conjectural. The smaller ingots, which are made from one pot of steel, vary from 3½in. to 5in. square. The steel is sometimes teemed directly into the mould by hand-pouring, but in some works clay funnels are placed on top of the mould to direct the stream down the centre of the mould to avoid cutting its wall, as might happen if the stream impinged on it. Funnel pouring is also advantageous when two pots are to be combined to make a larger ingot, as the steel can be poured into the funnel from opposite sides at the same time.

The strong tendency of high-speed steel to pipe is checked considerably in most plants by the use on each ingot of a hot "dozzler," which is a clay ring preheated red-hot, that is placed on the ingot top and filled with molten steel. This arrangement keeps the top of the ingot molten long enough so that the pipe is of diminished size and nearly or quite all contained within the part of the ingot surrounded by the "dozzler." The proportion of the ingot to be rejected on account of the pipe is therefore much decreased. The moulds are usually closed at the bottom end and are either made with parallel walls or tapered so that the ingot is larger at the top than at the bottom. The moulds must be split when the walls are parallel, and are sometimes split when the ingots are tapered.

High-speed tool steel as cast has a coarse structure and dark colour as compared with the structure and colour of simple steels of the same carbon content. A corner is broken from the top of each ingot, to show the grain, and the ingots when hand-poured directly from the pots are classified by the eye as in the production of simple crucible steels. If the ingots are cast from the large ladle a test is taken for analysis which determines the disposition of the whole ladleful of steel. As a rule the ingots show a strong columnal structure or arrangement of crystals whose axes are normal to the cooling surface. Some makers refer to the structure as a "lemon structure," the crystals of the metal being thought to resemble the cells forming the pulp of a lemon. If the casting temperature is lower than usual, this lemon structure may be absent, and in that case the absence of the ingot will have a much finer grain than the ingots cast at the usual higher temperature. The subsequent heating and working of the steel entirely destroys the crystalline structure of the ingot, and the worked steel, on a fresh fracture, shows a most beautiful porcelanic structure.

The ingots run from 3½in. by 3½in. to 16in. by 16in., but most of them are from 5in. by 5in. to 9in. by 9in. For hot-working they are heated in a furnace chamber having a temperature of about 1180° C. (2156° Fah.). At this high heat the steel may be worked satisfactorily under the hammer or press and may be quickly worked down to the dimension desired.

Composition of High-speed Tool Steels.—The tendency of the makers is toward a somewhat uniform composition as regards the contents of the alloying elements, whose benefits have become fairly well known, and whose use as a consequence may be considered as established. Specifically, these alloying elements are tungsten and chromium. The addition of vanadium and cobalt in important proportions is considered by some makers to give distinct improvement to high-speed steel, and some vanadium is almost always present. The analyses of steels shown in the accompanying table are considered to be good commercial steels.

Samples D—1 and E—1 gave excellent results in a competitive test, whereas samples D—2, D—3, E—2, and E—3, manufactured by the same makers, gave distinctly inferior results in the same shop. The occurrence of nickel in four of the samples may have been accidental, having been due to nickel in some of the scrap steel used in the charge. Most makers now put in vanadium, and steel like that represented by sample G, which had the highest vanadium content of all the samples represented in the table, was the winner in a recent competitive test.

The average specific gravity of the steels represented in the table was about 8·8, the increase over the specific gravity of iron being due chiefly to the tungsten content. There are so many factors beside the ultimate composition that affect the value of high-speed tool steels that no conclusion can be drawn from the analysis alone. The melting, hot working, and heat treatment all must be done correctly or the final result will not conform to expectations.

Carbon.—The proportion of carbon aimed at in high-speed tool steels is about 0·65 per cent., which in a simple steel would not be enough to give the maximum hardness even if the steel were heated above the critical point and quenched in water, and still less so when the steel is cooled as slowly as these steels are in their treatment. This shows that the carbon acts in a different way from what it does in simple steels, as is discussed later.

Tungsten.—Tungsten is well established as a most important if not indispensable ingredient of commercial tool steels, being almost or quite universally used in quantity therein. The best proportion of tungsten, all things considered, seems

* From a bulletin on "The Manufacture and Use of Alloy Steels," published by the United States Bureau of Mines.

to lie between 16 and 20 per cent., the tungsten content in 95 per cent. of all the American steels coming within these limits. Some published analyses of European high-speed tool steels show a higher content of tungsten than this, but American makers generally agree that any tungsten in excess of 20 per cent. adds nothing to the usefulness of the steel, and they therefore make that proportion the upper limit of the amount added. One effect of the tungsten is that the best percentage of carbon in high-speed steel is but about half that required in simple tool steels intended for the same kind of service.

Chromium.—The effect of chromium in high-speed tool steel, as in other steels, is undoubtedly as a hardener, entering into the double carbide of tungsten and chromium which gives or causes the proper cutting edge. Although the proportion of this element present in these steels varies considerably, it is always large, perhaps never less than 2 per cent. or more than 6 per cent. in American steels, and in European steels the upper limit is at least 9 per cent.

Molybdenum.—The use of molybdenum in high-speed tool steels is being generally discontinued. Some makers for years manufactured molybdenum tool steels, but as a rule they have either wholly discontinued its use or use a much smaller proportion than formerly, employing it as an auxiliary rather than a major constituent. The effect of molybdenum is similar to that of tungsten, but is more intense in that 1 per cent. molybdenum is currently considered to give about the same or greater hardening effect than 2 per cent. of tungsten. It gives a fine cutting edge.

Vanadium.—Vanadium is used for high-speed tool steel in varying amounts, most makers using at least 0·5 per cent., although some run the vanadium content up to $1\frac{1}{2}$ or $1\frac{3}{4}$ per cent., or even more, considering that such an addition increases in an important degree the value of the steel for tools. The effect of vanadium is considered to resemble in some ways that of chromium in increasing the hardness or red-hardness of the cutting edge. High-speed steels containing vanadium are generally classed as "superior" steels and many, though not all, makers and users consider them distinctly better than the "standard" steels containing no vanadium, both on account of their actual cutting qualities at high speeds and on account of the length of time a tool will cut before it needs regrinding. The true value of vanadium in high-speed steels must probably be held as not yet fully determined. The analyses given in the table show that all the samples contained vanadium, but in greatly varying amounts.

Cobalt.—Cobalt now threatens to change tool-steel manufacture because of the properties it imparts. The recent great decline in price following the increase of the supply from the silver ores of the cobalt district in Ontario naturally led to its trial as a steel alloying element, and some most excellent high-speed steels containing, in addition to the usual ingredients, about four per cent. of cobalt, have been obtained. This result was hardly to have been expected in view of the experience with nickel, which cobalt much resembles, as nickel has been condemned by nearly every manufacturer as not being a desirable ingredient of high-speed tool steels, because of the effect it has of making the edge soft or "leady." The cobalt steel, however, has shown, in some products at least, increased ability to hold its edge in work. One user of cobalt steel found it better suited for turning manganese steel than any other steel he tried, his success being so marked as to make it practically a commercial operation. Manganese steel is so hard as to be considered practically unmachinable, the usual practice having been to finish it by grinding when necessary. The valuable effect of cobalt is claimed to be that it increases the red-hardness of high-speed tool steel, enabling the steel to cut at a higher speed.

Copper.—Copper has been considered to be highly injurious in high-speed tool steel, even as little as 0·05 per cent. being inadmissible; and it is thought to be particularly harmful if much sulphur is present in the steel; also the higher the carbon content the more harmful is the copper.

Sulphur and Phosphorus.—Sulphur and phosphorus, which are so deleterious in simple tool steels, are considered to be somewhat less so in high-speed steels, in which the effect is either modified or else masked by the large quantities of other ingredients. Some commercial brands of high-speed steels have as much as 0·05 per cent. of each of these impurities, to which no inferior quality is attributable.

Heat Treatment of High-speed Tools.—The heat treatment given to high-speed steels for the commoner uses as lathe and planer tools has generally been simplified to heating to incipient fusion and quenching with oil. Cooling by an air blast and double treatment, which were formerly recommended, are now not common, except that a second (drawing) heat is given to milling cutters and similar tools, the temperature imparted to the tool depending on the material to be cut.

The treatment is usually done by the blacksmith, who heats the tool in his forge fire and then immerses it in a tank containing enough oil so that its temperature does not rise materially. Ten gallons of oil is a common quantity to use when the size and number of the tools is moderate, as in most shops. The fire is a deep compact coal fire, the coal in the centre where the tool is heated being pretty thoroughly coked, that is, most of its volatile matter distilled out. This manner of heating has the advantage that free oxygen does not get at the tool to oxidise it, but its environment is non-oxidising or even reducing, owing to the presence of an excess of burning carbon surrounding the tool. Any flame is more or less oxidising, at least unless heavily charged with smoke or free carbon, and a piece of steel heated directly by a flame as in the ordinary heating chamber of a furnace is likely to be somewhat oxidised on its surface, the depth to which the oxygen penetrates varying according to the conditions, particularly the temperature, the access of air, and the length of time. Heating in a muffle will also result in oxidising the steel unless extraordinary precautions are taken to keep out oxygen or to consume all that enters. The temperature of quenching, usually about 1260° C. (2300° Fah.), is determined by the fusion of the scale and its visible collection into drops or beads on the surface of the tool.

Results of Analyses of High-speed Steels made in 1913 or 1914.

Sample.*	C.	Mn.	Si.	S.	P.	Cr.	W.	V.	Co.	Ni.	Mo.	Remarks
	%	%	%	%	%	%	%	%	%	%	%	
A	0·65	0·15	0·20	0·02	0·03	4·75	17·50	0·90	—	—	—	
B—1 ..	0·66	0·27	0·14	0·04	0·05	4·51	17·48	0·70	4·22	0·17	—	
B—2 ..	0·74	0·31	0·13	0·04	0·02	4·20	15·63	0·67	2·70	—	—	
B—3 ..	0·63	0·14	0·07	0·04	0·05	4·26	17·16	0·45	3·80	0·20	—	
B—4 ..	0·69	0·34	0·14	0·03	0·04	5·28	16·35	0·64	5·28	—	—	
C—1 ..	0·66	0·22	0·17	0·03	0·02	3·44	16·51	0·73	—	—	—	
C—2 ..	0·64	0·21	0·16	0·03	0·03	3·30	16·06	0·66	4·02	—	—	
C—3 ..	0·67	0·33	0·25	0·02	0·02	3·85	16·06	0·70	—	—	—	
D—1 ..	0·75	0·28	0·36	0·03	—	4·10	19·00	0·75	—	—	—	Good.
D—2 ..	0·68	0·38	0·40	0·03	—	4·65	17·85	0·53	—	—	—	Inferior.
D—3 ..	0·69	0·36	0·38	0·04	—	4·67	17·90	0·50	—	—	—	Do.
D—4 ..	0·57	0·20	0·26	0·02	0·03	4·82	15·38	0·50	—	—	—	Do.
E—1 ..	0·61	0·23	0·35	0·04	—	4·10	17·20	1·00	—	—	—	Good.
E—2 ..	0·68	0·45	0·40	0·04	—	4·00	14·26	1·09	—	—	—	Inferior.
E—3. ..	0·70	0·50	0·39	0·05	—	4·08	14·50	1·07	—	—	—	Do.
E—4 ..	0·60	0·23	0·12	0·03	0·02	3·90	17·27	0·90	—	—	—	Do.
F	0·64	2·29	0·12	0·02	0·01	4·39	16·09	0·59	—	0·28	—	
G	0·72	0·37	0·18	0·03	0·02	4·50	13·30	2·50	—	—	—	
H—1 ..	0·77	0·16	0·21	0·02	0·02	4·05	18·64	1·35	—	—	—	
H—2 ..	0·67	0·16	0·20	0·02	0·02	4·66	13·86	1·08	—	—	—	
I	0·64	0·23	0·29	0·02	0·02	4·57	19·10	0·54	—	—	—	
J—1 ..	0·64	0·30	0·26	0·02	0·01	2·93	18·71	1·22	—	—	—	
J—2 ..	0·71	0·14	0·26	0·03	0·03	2·97	18·21	0·97		—	—	
K—1 ..	0·55	Tr.	0·23	0·02	0·04	4·46	16·05	0·80	4·72	—	0·72	
K—2 ..	0·70	Tr.	0·18	0·01	0·02	4·25	15·50	0·88	4·72	0·18	0·67	
K—3 ..	0·74	0·31	0·13	0·04	0·02	4·20	15·63	0·67	2·70	—	—	

* Samples A to I represented American steels, the numerals indicating different samples from the same maker. Sample J represented an English steel. Sample K represented a German steel.

Quenching is done by quickly plunging the heated tool into the oil as soon as it has reached the desired temperature and moving it about in the oil until cold. Cooling in oil is thought by some to give a better tool than cooling in the air blast, one reason seemingly being the protection of the steel from free oxygen while it is hot enough to be oxidised thereby. The oxygen of the air blast forms a scale of oxide on the hot steel and the oxygen probably penetrates the metal below the scale to some extent, injuring the quality as deep as it goes. A tool on its second grinding when the oxidised metal is removed may then give better service than on the first, unless the first grinding has for that reason been heavy enough to remove the oxidised metal.

In some shops, however, the original treatment recommended by Taylor and White is given, the cutting edge of the tool being heated to incipient fusion and then immersed in a bath of melted lead at about 565° C. (1050° Fah.). The heating is done in a small furnace over a deep coke fire, blown by an air blast, so that the environment of the tool

while being heated is substantially non-oxidising. Flames of carbonic oxide play out of the openings through which the tools are inserted, indicating little if any free oxygen within. In these shops, however, milling cutters and other tools that are machined to a particular form are treated by heating them to a slightly lower temperature, in order not to damage the cutting edges, and then plunging them into cold oil.

When cooled to the temperature of the lead it is taken out and placed in an air blast to complete the cooling. Some tools desired to be especially tough so as not to break in service are given a second heating to 565° C. and then cooled in the open air or air blast if saving time is important. High-speed steel when well annealed will bend considerably without breaking, even in as large a section as 2½in. by 1¼in., the bending being edgewise, as in a tool at work. Whether a rapid steel is made harder by the heat treatment given it depends somewhat on the condition of the bar before treatment. If it has previously been annealed, the treatment hardens it, whereas heat treatment may not harden a piece in the natural state. The hardness of the steel when cold is not the determining factor of usefulness in any case. It is the hardness when heated under conditions of work. The cutting edge of a rapid-steel tool at work is probably never as hot as the metal just back of it, where the heating caused by the friction of the chip, as it is deflected and rubbed hard on the tool, is most intense. The edge itself is kept relatively cool by the cold metal flowing upon it.

(*To be continued.*)

DIESEL ENGINE USERS' ASSOCIATION.

THE June meeting of the Diesel Engine Users' Association was held at the Institution of Electrical Engineers at a rather later date than usual. It was arranged that this meeting should be held during the week that the Incorporated Municipal Electrical Association were holding their annual meeting in London, so that several members who perhaps otherwise could not often conveniently come up to town might have an opportunity of attending the Diesel Engine Association's meeting. Mr. A. J. C. De Renzi (Corporation of Newcastle-under-Lyme) made a suggestion that the association should hold one meeting in each year in an important centre outside London, such as Manchester, Birmingham, &c., so that engineers in those parts who took an interest in the work of the association might take the opportunity of attending its deliberations and discussions. He referred, however, to the fact that the main advantage of membership consisted not so much in actual attendance at meetings, but in the receipt of the communications, reports of proceedings, and useful data on various subjects which were collected by the association and circulated among its members. This was emphasized by the fact that the great majority of the members were located in distant parts of the country, in the oversea dominions, and in foreign parts. The president, Mr. Geoffrey Porter (Corporation of Worthing), stated that Mr. De Renzi's suggestion would receive the careful attention of the committee.

The Use of Tar Oils as Fuel in Diesel Engines: The German Patent.—A motion by Mr. H. Leslie Dixon (Leatherhead), seconded by Mr. C. O. Milton (Maidenhead), that the association should support the application of the Suffolk Electricity Supply Company, Ltd., to the Board of Trade for the voiding or suspension during the war of the German patent in regard to "improvements in internal-combustion engines" to enable tar oils to be used as fuel, was discussed. It was pointed out that although at present any royalties would be paid to the Public Trustee, the Germans might eventually benefit as a direct result of the war in consequence of the increased price of crude petroleum oil, which led to the present demand for tar oils as fuel for Diesel engines. Further, on public and patriotic grounds, the association should support any movement which would tend to the preservation and most economical use of the coal reserves of the country. The motion was carried unanimously.

Oil Engines and Steam Engines in Combination.—An interesting paper on this subject was read by the president, Mr. Geoffrey Porter, in which he discussed the problems met with in extending a comparatively inefficient steam-driven generating station of about 1,500 kw. capacity, of which there are large numbers in various parts of the country. He dealt with the subject from the point of view of capital costs and working costs, and produced tables showing comparisons of actual results obtained by the introduction of Diesel engine plant at various works. He referred to troubles in the working of Diesel engines, which were to be expected in connection with the development of any new form of engine, but stated that in his own experience he could not desire better or more consistently reliable working than he had obtained. All the examples of generating stations in which Diesel engine plant had been put down as an extension to the steam plant showed a remarkable diminution in working costs. An important advantage of the Diesel engine over steam plant was that any irregularity or inefficiency in working became obvious at once, and could receive prompt attention, and the author was convinced that a Diesel engine plant could much more readily be kept in good economical working condition than the average steam plant.

Fuel Oil Supplies.—Before concluding Mr. Porter referred to the benefit which Diesel engine users had obtained from the discussion of certain important subjects at recent meetings of the association, such as the lubrication of Diesel engines, and troubles in connection with air compressors. The question of fuel oil supplies was also one of the greatest importance, and the present war had opened our eyes to the manner in which this great and rich country had become dependent on others for absolute necessities. The fuel oil question could be, and would be, solved by our own chemists and engineers. The matter was of more than sectional interest, it was of national interest. Our engines would work well on the products of the distillation of coal, that coal which to-day was used so uneconomically that, under the best conditions, only 10 to 20 per cent. of its energy value is utilised, the rest going to waste. Continental users and manufacturers of Diesel engines had used tars and tar oils with success for many years, and we should do so too. There was an opening for a new market for the by-products of gasworks, blastfurnaces, gas producers, and low-temperature coal distillers which should be well worth cultivating. When that was established we should, at any rate in one direction, be an independent people. England's greatest commercial asset was her coal. Her position in the trade of the world was chiefly due to this gift of the gods. It was the business of manufacturers and users of power plants in particular that it should be adequately conserved. In working our coal deposits we were indeed living on our capital; the greater reason, therefore, to use it to the best advantage.

The next meeting of the association will be held on Wednesday, July 12th. Further information and particulars concerning the association can be obtained from the hon. secretary, Mr. Percy Still, 19, Cadogan Gardens, London, S.W.

HEAT TREATMENT OF DROP FORGINGS.

IN a paper presented by W. C. Peterson at the annual convention of the American Drop Forge Association, the author summarised the heat treatment of forgings as follows: Forgings must not be heated too hot. They should be worked continuously down to the finishing temperature. This finishing temperature should not be too far above the critical range, nor below it. The influence of the heat-treatment of forgings is dependent more or less upon the proper hot working of the forgings. Collectively these facts tend towards a suggestion which could be worked out to the benefit of both the vendor and consumer of forgings alike. Since quality is the watchword of the present "up-to-the-minute" manufacturer, and since we know that uniformity is absolutely essential to good forgings, could it not be arranged to standardise more than ever such operations as proper working temperatures, proper finishing temperatures, number of blows to a forging, &c.? Such standardisation would mean increased output and likewise better forgings. In time, studying along these lines, it might be found that the introduction of motion study would play a very important part in producing more forgings of a very high grade of workmanship.

Personal.—Dr. Henry Marion Howe, Professor of Metallurgy of Columbia University, New York, has just been elected an honorary vice-president of the Iron and Steel Institute. The Bessemer Gold Medal of the Institute was awarded to Dr. Howe in 1895 in recognition of his great work in the advancement of metallurgical science and knowledge.

SOME BOILER PROBLEMS AND THEIR SOLUTIONS.*

BY B. THOMPSON.†

(*Concluded from page 504, Vol. XXXVII.*)

ALL classes of boilers suffer if feed water is bad. It should if possible be of good quality. If it is impure the best possible method of dealing with it is some apparatus outside the boiler in which the water is purified of any deposit or scale-forming matter, and any acid tendency neutralised. Treatment of feed water by re-agents inside the boiler is the plan most commonly adopted, various chemical bodies being used for this purpose. There is no re-agent or composition which is suitable for all feed waters. Each case should be treated on its own merits, and before deciding on the course of treatment for any feed water it should be analysed by some independent analyst who has no axe to grind, *i.e.*, who does not sell the chemical compound to be used.

Indiscriminate use of boiler compositions sometimes leads to serious damage to steam boilers, and in the majority of cases to needless expense. The use of composition inside a boiler, even if ineffective, does not render it unnecessary to clean the boiler. Composition cannot be made into a laundry maid, and usually all that takes place when composition is doing what it is intended to do is that the scale or deposit is rendered soft and comparatively easy to remove and the boiler requires regular cleaning and scaling just as if no composition were used. When there is a large quantity of scale-forming matter in the feed water it will, unless removed by frequent cleaning out or by some other effective manner, rapidly accumulate in the boiler and very probably lead to dangerous overheating of the furnace plates or other parts of the boiler.

Grease or oil in feed waters is always objectionable, as either by the thickening of the water or forming of a film of grease on the plates it prevents free transmission of heat and leads to overheating with the consequent cracking, bulging, distortion, and increased wear and tear generally. Where a flour-like carbonate of lime or magnesia is deposited from the feed water the water is thickened, especially if grease or oil be present. Even a small amount of floury deposit may in conjunction with oil and grease lead to overheating. In some cases overheating is due to the formation of greasy deposit on the furnace plates obstructing the passage of heat through the furnace plates to the water. In other cases, although no accumulation of greasy deposit be found on the furnace plates, a mixture of oil or grease with the floury deposit renders the water like milk, preventing free ebullition of steam and so resulting in overheating.

Even if there was no danger of overheating, which there certainly is, all oil or grease should be kept out of the feed water as far as possible, for oil is a well-known non-conductor of heat, and it has been demonstrated that a film of grease one-hundredth of an inch thick offered a resistance to the passage of heat equal to a steel plate 10in. thick. In other words, grease offered a resistance a thousand times greater than steel, so I think you will agree with me that it is absolutely essential to keep the feed water as free from oil and grease as possible. If ever I find oil or grease or even traces of it in a boiler I try to find the source from which it comes, and then if possible have it stopped from getting into the feed water. I might say that in several cases I have found the drain pipes from the engine were led direct into the well from which the feed water was taken. This has been done with a view to saving the condensed water from the cylinder, but a better method of getting grease or oil into the boiler could not very well have been adopted, and all drains from engine cylinders should be led clear away from the feed water supply.

Sometimes grease will find its way from the engine foundations into the well from which the feed water is taken. I recently came across a case where there was a special pipe from the suction side of the feed pump to the flywheel race which in case of heavy rain got flooded. This water and also the oil and grease was then pumped out of the wheel race into the boiler. One source of oil getting into feed water is when the exhaust steam is run into the water in order to heat it, and in this case an oil separator should be fitted to the exhaust steam pipe. There are several fairly efficient separators now on the market. This applies to non-condensing engines only. Another source of oil and grease getting into the boiler is when the feed water is taken from the hot well of a reciprocating condensing engine, and it is inevitable that oil and grease more or less will get into the boilers unless means are adopted for removing the grease from the exhaust steam before it reaches the condenser or the feed water before it enters the boiler. To remove oil from the feed water, various mthods are in use.

Filtration alone is not satisfactory, as the greater portion of the oil is present in the form of an emulsion which, when examined under the microscope, is seen to consist of minute globules of oil in suspension. These globules are many times smaller than any filtering medium. The diameter of these globules being from 1/50,000 to 1/100,000 of an inch, and in consequence they pass forward through the filter to the boiler, where they are taken up by the deposit present. Extraction of oil may be accomplished by means of a separator from the exhaust steam before it passes to the condenser. The general principle of action of an exhaust steam separator is to materially reduce the velocity of the steam and to change the direction of motion. Then the oil settles out and can be collected. The majority of these vessels acts fairly well where the pressure does not fall below that of the atmosphere, but when interposed between the low-pressure cylinder of an engine and the jet or surface condenser the efficiency is not so good owing to the increased velocity of the steam, due to the vacuum and the impracticability of having a separator large enough to sufficiently reduce this velocity.

The chemical treatment combined with filtration consists of a formation in the nature of a gelatinous precipitate which will cause the oily globules to adhere to it, thereby forming a sticky residue which can be removed by filtration. This is one of the most reliable methods; but even with this method special attention is required to filters in order to keep these clean, or oily deposit is liable to find its way through the filters to the boilers. The best method to adopt in general cases will vary according to circumstances. Where exhaust steam is used for heating the feed water the quantity of oil used in engine cylinders should be restricted to just what is necessary and not used as I have seen in some cases. There is a big difference between a piston being properly lubricated and to its being floated in oil. All modern and up-to-date engines are filled by a pump or other means of constant lubrication, which can be regulated (within certain limits) to any given quantity; but with some of the older types of engines the method of lubrication still retained is the large and wasteful oil cup fixed on the cylinder. When I say wasteful I mean it in this respect. The cup is filled, say, every hour, and then in some cases the valve at the bottom of the cup is opened full bore, and in other cases some attempt to regulate the flow of oil into the cylinder is made by partly opening this valve and then trusting to luck for the result, which is about all that can be done with this type of lubricator, as the oil cannot be seen in its passage to the cylinder and therefore the rate of flow cannot be regulated with any degree of certainty. What usually takes place in a case like this is that for a very short period an excessive amount of oil is passing into the cylinder and thence with the exhaust steam to the feed water. Then for the remaining part of the time, until the cup is filled again, the piston will be working practically without lubricant, which of course tends to cause undue wear and tear of the piston, cylinder, and valve, and increased friction, which means increased fuel consumption.

I will now deal with cleaning of boilers. It is necessary that boilers should be opened out regularly for internal cleaning. The proper period for this depends on the nature of the feed water and the amount of work done. The exact period for cleaning a boiler should be determined by careful consideration and observation of the working of the boiler. It is important, but impossible in a paper like this, to give an approximate time that should be allowed between one cleaning and another, for in some cases owing to the feed water and the amount of water evaporated, there will be as much scale deposited on the plates in a week as there is in other cases in a month; so that each case must be decided on its own merits. The internal cleaning of boilers is a very important matter, and should receive most careful attention from owners and engineers in charge of steam plants generally, for accumulation of scale is

* Paper read before the Stoke-on-Trent Engineers and Engineering Students' Association.

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not only objectionable because it prevents the proper transmission of heat through the plants, but it may also be dangerous, as it conceals any wasting or corrosion which may be going on beneath it, and many serious explosions have arisen from this cause.

I regret to say that the scaling of boilers does not receive the attention it might or should do in many cases. Even after the boiler is supposed to have been prepared for inspection it is no uncommon thing to find the plates buried in scale to such an extent that neither seams nor rivets can be seen in the lower part of the shell, and I have on more than one occasion found the water space between the furnaces and shell choked with deposit. Then, if the furnace plates bulge or crack, or the circular seams in the shell spring open and start leaking, which is no unusual occurrence, the owners wonder how it happened and want to blame either the boiler or the makers for it. But what I wonder at is, there are not more accidents than there are when boilers are worked under these conditions, and it speaks volumes for the material and construction of the modern boiler. Another important point is the waste of fuel in boilers heavily coated with scale. I feel certain that if owners and engineers generally were aware of the excessive waste of fuel due to this cause they would take greater precaution to ensure that the boilers were kept more free from scale than they are at present in a number of cases, to say nothing of the risk of a serious accident and the shortening of the life of the boiler due to the frequent overheating of the plates when boilers are worked in this condition. I may say that among engineers scale is a well-known non-conductor of heat, and it has been stated that theoretically $\frac{1}{16}$in. of average scale necessitates the expenditure of 16 per cent. more fuel, $\frac{1}{4}$in. of 50 per cent., and $\frac{1}{3}$in. of 150 per cent. extra fuel to generate the same amount of steam, which is a very serious item considering the price of fuel at the present time.

There is one method of cleaning boilers sometimes adopted which, taken from an economical point of view, I do not agree with, viz., where boilers are cleaned internally about every six weeks or two months, and the flues are allowed to run six months, and in some cases twelve months between each cleaning. Some owners and managers seem to think that it does not matter about soot being in the flues so long as the steam can be maintained in the boiler. It is a case of "out of sight out of mind," and I feel certain if they had the least idea of the amount of fuel absolutely wasted when the flues are practically choked with soot they would not treat this matter so indifferently as they do at present. Soot is a well-known non-conductor of heat, and it is no uncommon thing for me to find the flue plates heavily coated with soot hanging like snow flakes even after the boilers are supposed to have been prepared for inspection. Of course I am fully aware that the nature of the fuel and the draught has a considerable bearing on the soot deposited on the plates and in the flues, and what I would suggest to those in authority over boilers is to have them cleaned thoroughly both internally and externally, and then note carefully week by week the amount of fuel used. If the load is of a fair average, and the boiler is working up to anything like its normal capacity, they will find, after about the third week, an increase in the amount of fuel used, which will gradually increase week by week until the boiler is cleaned again. Of course I admit this increase will vary according to the nature of the fuel and feed water used, but when scale and soot are allowed to accumulate on the boiler plates the amount of fuel will increase accordingly. The plan I have just mentioned, if carefully adopted, will give a fairly good idea of how boilers should be cleaned.

With regard to the cooling and emptying of a boiler, this should be done as gradually as possible, and when there are two or more boilers, so that one can be cleaned while the others are at work. The best plan is to allow the boiler to stand for two or three days before running the water off, for rapid cooling tends to cause straining or fracture at the seams, and the slow cooling avoids this. Of course, where there is only one boiler it is not feasible to let it stand two or three days, and the man in charge has to do the best he can under the circumstances. There is one method of emptying and cooling a boiler that is the most objectionable I know, and that is to blow the boiler off under pressure and then to run cold water in, in order to cool it more rapidly. This plan should never be adopted, as it always is likely to seriously injure the boiler. The sudden strains which are set up by the cold water running on to the hot plates may set up fractures through the lines of rivets forming the seams, which cannot be detected in the ordinary way, and which may lead to explosions and loss of life when the boiler is worked again. I do not recommend even the following, but it is probably the least objectionable method of rapid cooling; that is, the plan of introducing cold water at the same time as the hot water is run out. Where there is a large amount of water available for carrying out this plan, the boiler is fed at the same time as the hot water is allowed to run away at the blow out, the inflow being adjusted to the same rate as the outflow. By this means the whole body of water in the boiler is cooled gradually, and, of course, the temperature of the plates below the water level follows that of the water. This plan ensures the cooling of the boiler shell without straining it so much as is done when the boiler is blown off under pressure. But whatever method is adopted, the cooling of the boiler should be as gradual as the circumstances will permit.

While on the question of cleaning, I should like to mention the safety valves, which are most important fittings, and should receive most careful attention. They should be kept clean and in good condition. Whatever the type of safety valve used, when the boiler is working it should be tested at least once daily to make sure that it is in thorough working order, and when the boiler is off for inspection these valves should be taken adrift so that they can be examined at the same time. The best and most reliable type of valve for stationary boilers is the internally-loaded pendulous dead weight type, which has been improved during recent years to such an extent that it is practically on the swing all the time the boiler is working, and can be spun round as if it was on ball bearings and still be steam tight.

When lever and weight safety valves are fitted there should be one weight only adjusted to give the maximum load when it is at end of the lever. Adding odd weights to obtain the desired pressure is objectionable and dangerous and is liable to lead to overloading, which I have found many times. When properly designed with knife-edge fulcrum and no wings in the valve, this type of valve is satisfactory. Many valves of this type are, however, unsatisfactory and require special care to ensure that they lift freely when blowing off pressure is reached. The safety valve in all cases should be connected to the steam space of the boiler by a separate branch, which serves for this fitting only.

I have come across numerous cases of maltreatment of safety valves, and just to give you an idea of the risks some people take, I will mention several cases. In one case I found the lever wedged down by a chisel driven into the guide fork. This boiler was supposed to have been prepared for a thorough examination when, in accordance with the Factory Act, all mountings should be opened up for inspection. In another case of a Lancashire boiler with only one safety valve, which was a compound high-steam and low-water type, the boiler was working. I lifted the lever, and as the steam did not escape past the valve, I tried to ascertain the cause, and found the centre spindle for the low-water alarm had been removed and a sheet-steel disc about $\frac{1}{8}$in. thick had been fixed between the joint to valve casing and the mounting on the boiler. This entirely blocked the thoroughfare to the valve. On enquiring the reason for this, the engineman said the valve had been leaking and he had put in this disc to save steam. Another case, about three years ago, was a silk mill with a Galloway boiler about 45 years old. I found it working without safety valve entirely. The valve had been removed about a fortnight ago to have a new seating and valve fitted.

I came across a case recently where they have a rather old Cornish type of boiler, fitted with an ordinary lever and weight safety valve, and at one of my periodical visits I found a board about 6ft. by 12in., one end of which was resting on the wall at front end of the boiler while the other end was on the safety valve lever. On this board were three large saggers, such as are used for sanitary ware. These saggers had been put there to dry. I think the most deliberate case of overloading I have ever met was in this district a few years ago. This was a vertical boiler fitted with an ordinary lever and weight safety valve. When I arrived at this place I found that, in addition to the ordinary weight, there were two cog wheels secured by a piece of strong wire, a miner's lamp, and a fire poker about 7ft. long, all hung on the end of the safety valve lever.

These are only a few of the cases I have met at different

times, and I have mentioned them to show the risk sometimes taken, due, in my opinion, more to ignorance of the consequences than to carelessness, which shows how essential it is for the owner of a steam plant to make sure that the man in charge of the boiler is qualified for the job.

External corrosion, that is, wasting of the outer surfaces of the plates in one or other of its many forms, is a common cause of deterioration of steam boilers, and numerous serious explosions have occurred due to this. Dampness or moisture in contact with the plates is almost certain to set up corrosion and wasting sooner or later. It is sometimes due to leakage past the riveted joint of the mounting blocks, and also from the ring seams and longitudinal seams of the boiler itself. In other cases, as about the top and flue covers of the boilers, or the front cross walls or the side seatings, the dampness may arise from external causes. The front cross wall is frequently made damp about the blow-off pit by the practice of slacking ashes against the front end plate. This practice often leads to serious corrosion of the bottom of the end plate of the angle iron and other adjacent parts, thereby necessitating extensive repairs to the boiler and replacement of the blow-off pipe and cocks. Leaky water gauge cocks and defective drainage of the blow-off pit are also common sources of dampness and consequent corrosion about the blow off. Ashes should not on any account be slaked against the front end plate, neither should they be allowed to lie there even when not slaked, for if there should be air leakage at the front end of the external flues, there is always the possibility of the ashes getting into a glowing heat. This, acting on the lap of the front end plate and the angle iron, causes overheating and springing of this seam, resulting in leakage past both the seam and rivets. The consequence is that this seam has usually to be re-riveted before it can be made tight, and even then, unless this practice be discontinued, leakage will soon be as bad as ever.

Generally, when moisture gets into brickwork it is absorbed by it and is kept in contact with the plate. This, the most favourable condition for external corrosion, causes rapid deterioration of the parts of the boiler in contact with the brickwork. When there is any indication of damp brickwork, the part should at once be bared so that the source of the moisture may at once be traced and stopped before serious damage is done. On the tops of boilers leakages from steam pipe joints overhead often cause dampness of the brickwork and wasting of the plates. In the case of unhoused boilers, the moisture due to rain may run down into the brickwork and, kept in contact with the plates, set up serious corrosion. Such parts should be bared regularly, but one cannot very well fix a definite time when this should be done. A great deal depends on circumstances, and the general condition of the brickwork. In some cases joints are kept well cemented, a good coat of tar is given to it occasionally, while the brickwork over the side flues slopes away from the boiler, which is the correct thing. Defective roofing over housed boilers is another obvious but frequent source of boiler corrosion.

I may mention a Cornish type boiler in this district. The feed water tank was on two brick pillars just outside the boiler house. This tank was supplied with water from the town main and regulated by an ordinary stop cock about 4ft. above the level of boiler. At each of my visits for some considerable time, I noticed a little leakage past the gland of this cock, and the water was dropping on to the brickwork about 3ft. from the boiler. There were not the usual flue covers over the side flues, but the brickwork was set in. On one occasion I had this brickwork removed, and found the plates corroded to about $\frac{1}{16}$ in. deep. The brickwork was put back, but the leakage past the water cock was not stopped. This leakage was not much, but I suppose was going on continually. Anyhow, two years later, when making the annual thorough inspection, I noticed oxide on the plates near the brickwork in the right side flue, so, after some grumbling by the manager about the unnecessary expense, &c., I was causing them, he had the brickwork removed and I found the first, second, and third rings of shell corroded to such a serious extent that it was absolutely unsafe to work the boiler at any pressure. The reason for the rapid corrosion which had taken place in two years time was that when the brickwork was put back, lime mortar was used, and although I had never seen any dampness on the top of the brickwork, the water had percolated between the second and third courses and was thus hidden from view without removal. It was 3ft. from the boiler to where the water was dripping on to the brickwork. The owner complained to me that he was not aware of this leakage past the gland of the stop cock or he would have had it stopped. I told him I had pointed it out to the manager at each visit, and also he would find it in all my reports for several years past. He said he never read my reports, but this had taught him a lesson. This is not an isolated case, but an example to show how essential it is that boilers and their surroundings should be kept as dry as possible, and in case of doubt of dampness no hesitation should be made about the removal of brickwork or other covering in order to make sure as to the condition of the plates.

It is not advisable to cover the crowns of boilers with brickwork. The covering should be non conducting and made of a composition such that, if there be any leakage beneath, the covering will quickly indicate this by softening.

One of the commonest troubles in the working of a boiler arises from leakage at the seams. Such leakage may be due either to defects of construction or to bad treatment. Amongst the defects of construction are: Plates not bedded together; rivet holes not fair; rivets not filling the rivet holes; rivets not gripping the plates sufficiently; insufficient caulking; fractures in the plate. In all modern boilers all rivet holes are, or should be, drilled from the solid plate after the plates have bent to form, and are fixed together in the position they will occupy when finally riveted up. After this drilling through the solid plate has been done, the plates are taken apart, the rough edges formed by the drill being removed by means of a countersinking tool. The edge of each hole is thus left with a slight countersink so that no burr remains to lie between the plates and prevent a tight joint being made.

Among defects of treatment which lead to leakage are: Excessive rate of working, neglect of cleaning; overheating; too rapid cooling to emptying; getting up steam too quickly; rapid variation of temperature causing straining. A case of steaming too quickly came under my notice in which with 80lbs. pressure the hand could be held quite comfortably on lower part of the front end plate.

If leakage be due to improper treatment, care should be taken to avoid the cause, but in nearly all cases in addition steps will have to be taken to make good the defective parts. If the leakage is only slight, as a rule a light caulking will be sufficient. This should not be done while the boiler is under pressure. It should be remembered that although leakages do not generally mean danger, yet occasionally they do indicate dangerous conditions. A number of serious explosions would have been avoided if the indications of leakage had received proper attention. Repeated chipping and caulking of seams is objectionable. If there is very severe leakage at a seam or the leakage is not stopped by light caulking it is often the best course to draw some of the rivets and to examine the plates through the rivet holes carefully, so as to ascertain whether there is an incipient fracture between the laps. Such fractures have caused a number of serious explosions and they often indicate their existence by causing leakage.

There are several kinds of fractures met with at the riveted seams of a boiler. The most common is the cracked out rivet hole. A defect of this kind is not usually serious unless a number of the rivet holes near together are cracked out, thus destroying the strength of the lap of the plate. In a longitudinal seam of the external shell cracked out rivet holes are more important than in the ring seams. The most serious form of fracture at rivet holes is the seam rip. This usually consists of a fracture passing through several consecutive rivet holes and entirely destroying the strength of the riveted seam. This is a serious defect in any part of a boiler, and was met with frequently in the cylindrical externally-fired boilers of the old type. But with the improved method of construction, better quality of plates, a number of inherent defects in the old type of boiler have now been eliminated.

Before closing the paper, I should like to say a few words about steam pipes. This important part of the plant does not in a number of cases receive the attention it should, neither from the point of view of efficiency or safety. Every year some lives are lost by fracture of pipes or valve seatings by water hammer, which can usually be traced to bad arrangement of the steam pipes or drainage of same and frequently both. For efficiency the piping should be as free from acute bends as possible and should be well covered with some good non conducting material.

For safety the piping should fall in the direction of the travel of the steam with a well pipe fixed in at the lowest point, which should be drained by a good trap and a separate hand-drain. In some cases a set of ordinary water gauge cocks and glasses are fitted to the well pipes in order to show that the drains are doing their work. In most main ranges of steam piping a drain cock is provided at or near the lowest point, and the owner is then satisfied that perfect safety is secured by the attendant opening the cock and allowing sufficient time for the water to escape before turning on the steam, but, unless the end of the drain pipe can be seen, the opening of the cock for a certain period is no guarantee that any of the water has been drained from the pipes.

Accidents due to water hammer may be summarised as follows: Water is allowed to accumulate in the space which was designed for steam only. The space is allowed to become charged with water arising from condensation of steam. At some stage of the operation when the pipe is partially filled with water, steam is admitted and disturbance is caused. In some cases the steam propels the water until it comes in contact with some point at which the strength of the pipe surface is not sufficient to stop or deflect the moving water. In other cases the water is violently propelled forward and afterwards recoils to the starting point. Of this type are the accidents in which the stop valve on the boiler is fractured by water which has accumulated in a pipe rising from the valve. In all cases it is obvious that water hammer is produced only when the water is caused (usually by wave action) to move from one place to another and is suddenly arrested from rapid motion. Try cocks if used must be very small and opened for a very short time, otherwise the discharge from them may be sufficient to disturb the surface of the water in the horizontal length of pipe and thus start the water hammer they are intended to prevent.

In nearly all cases of water hammer, the cause is the disturbance of a comparatively large water surface in a horizontal or inclined pipe in which water is capable of moving. Therefore, whenever there is any doubt about the presence of water in such a pipe it is dangerous to attempt to drain the water away without first shutting steam from the pipe. I may say that in nearly all cases recorded since the passing of the Boiler Explosions Act in 1882, the water hammer might have been prevented if those who set it in motion (and in many instances suffered from its effects) had understood the probable consequences of their acts.

STANDARD TEST SPECIMENS OF ZINC-BRONZE.

A BULLETIN on "Standard Test Specimens of Zinc-bronze," by C. P. Karr and H. S. Rawdon, has recently been issued by the United States Bureau of Standards. It covers an investigation of test bars made of a mixture consisting of copper 88 per cent., tin 10 per cent., and zinc 2 per cent. It is pointed out that the test piece should correspond to the type of casting so as to be representative of the principal physical properties of the latter. Where it is desirable to obtain a knowledge of the physical properties of a casting made in sand, the test bar should be cast in sand approximately at the same time and from the same heat. As a result of the experiments made at the Bureau of Standards, it is possible to secure specimens cast to size in sand and poured within a range of temperatures from 1,120° C. to 1,270° C., which will have a tensile strength of 37,000lbs. per square inch, an elongation of 15 per cent. in 2in., and a reduction of area of 14 per cent. Under conditions maintaining in regular foundry practice, using similar materials, such a test bar might be expected to have a tensile strength of 33,000lbs. per square inch, an elongation of 14 per cent. in 2in., and a reduction of area of 13 per cent. However, if a bar of similar character be heat treated to 600° C. in a furnace for 30 minutes and quenched or allowed to cool in the furnace to normal temperature, it may be expected to show a tensile strength of 36,000lbs. per square inch, an elongation of 25 per cent. in 2in., and a reduction of area of 24 per cent. The results of this investigation are summarised as follows:—

(1) The best type of test bar where the metal is to be cast into sand is the cast-to-size shape. If the metal be poured within the range 1,120° C. to 1,270° C. (2,048° Fah. and 2,318° Fah.), greater uniformity of tensile strength and ductility may be secured.

(2) It was anticipated at the beginning of these investigations that some one temperature would be found at which the best and most uniform results as to the two important physical properties —tensile strength and ductility—would be obtained; but the series of tests showed that instead of one such temperature there was a zone of temperatures, 1,120° C. to 1,270° C. (2,048° Fah. to 2,318° Fah.), at which good results might be expected anywhere within that favourable zone of pouring temperatures.

(3) The kind of mould to be recommended is dry sand, which should be poured either flat or vertical. The first method is more economical of time and labour, but has, however, no superiority over the vertical pouring in the matter of technical results.

(4) The results of the chill and best sand-cast test bar are of almost equal value if the chill bar be annealed at temperatures ranging from 500° C. to 700° C. (932° Fah. to 1,292° Fah.), but otherwise the former is inferior to the sand cast-to-size shape as a representative test bar. The advantages of the chill bar are that there are no moulding requirements, and that it can be poured by unskilled labour. Its disadvantages are that it is expensive to machine into shape and size required for testing, and it gives results both as to tensile strength and ductility that are misleading. The advantages of the cast-to-size shape are that it is easy to mould and inexpensive to machine into the shape and size required for testing. From the results obtained it is believed to be the form which should be adopted as standard for general foundry practice.

(5) Heat treatment is productive of increased ductility, and has a marked effect on the deformation produced by continuously increasing loads on specimens annealed in the temperature zone of 600° C. to 700° C. (1,112° Fah. to 1,292° Fah.), which is in accord with the results of other observers.

(6) As an alternative for the sand-cast specimen, if one prefers to work with a chill-cast specimen, as is the case in some foundries, the results show for the few observations taken that when annealed between a temperature range of 500° C. to 700° C., a normalised chill bar is secured which is comparable to the sand cast-to-size shape. The specimens annealed and quenched offer no appreciable superiority to the specimens annealed and cooled slowly.

(7) The average density of sand-cast specimens is about 8·58 and of chill-cast about 8·6.

(8) The elastic limit of this zinc-bronze varies from 15,000lbs. to 17,000lbs. per square inch.

(9) The cooling curves show that the melting point of the alloy is about 980° C. (1,796° Fah.), and that there is a pronounced transition point at 780° C. (1,436° Fah.) and another feeble one at 530° C. (986° Fah.).

(10) In the accompanying table is recorded a summary of all the results obtained for physical properties arranged in terms of the type of casting.

General Averages of all the Observations taken.

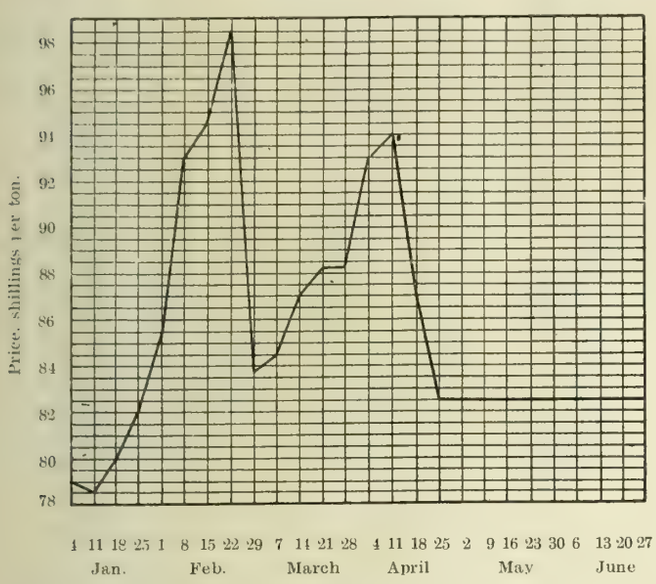
No. of bars	Shape.	Tensile strength. Pounds per square inch.	Elongation in 2 in. Per cent.	Reduction of area. Per cent.
217	Cast to size	37,869	15·5	14·7
161	Cylindrical	32,832	14·9	13·9
95	Barrel	32,029	14·2	13·8
88	Chill cast	36,512	6·3	6·9
21	Sand cast, annealed	38,190	27·0	26·0
16	Sand cast, quenched	39,810	26·9	24·2
5	Chill cast, annealed	31,160	17·0	16·7

In all of the above it is to be borne in mind that only pure copper, tin, and zinc have been used, and the results obtained are characteristic of variations in foundry practice on virgin metal only once or twice melted. The presence of scrap containing small amounts of lead, manganese, iron, and other ingredients which might influence the results of the tests with a standard bar are thus eliminated.

As a result of these investigations the following suggested specifications for the preparation of standard zinc-bronze (copper 88 per cent., tin, 10 per cent., and zinc 2 per cent.) have been prepared: Weigh out the required quantities of electrolytic copper, Straits tin, and Horsehead zinc. Cover the bottom of the

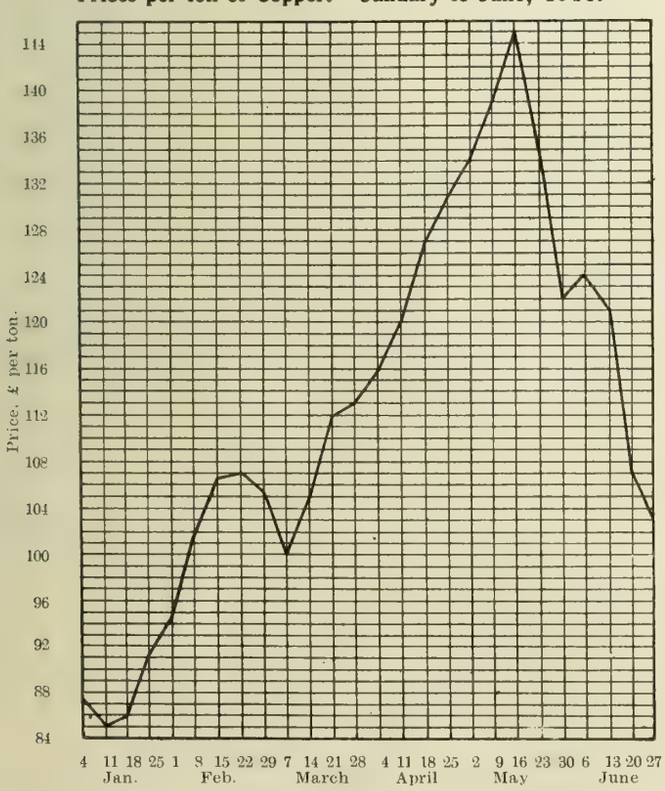
crucible with pieces of charcoal about the size of a hickory nut. Put in all the copper the crucible will hold, and cover the surface with small pieces of charcoal (no dust). Should the crucible not have the capacity to contain all of the copper charge, heat the charge contained until one or two of the pieces of copper are melted, crowd the remainder down into the molten mass, and add the remaining copper, bring the whole charge into a molten

Prices per ton of Cleveland Iron. January to June, 1916.



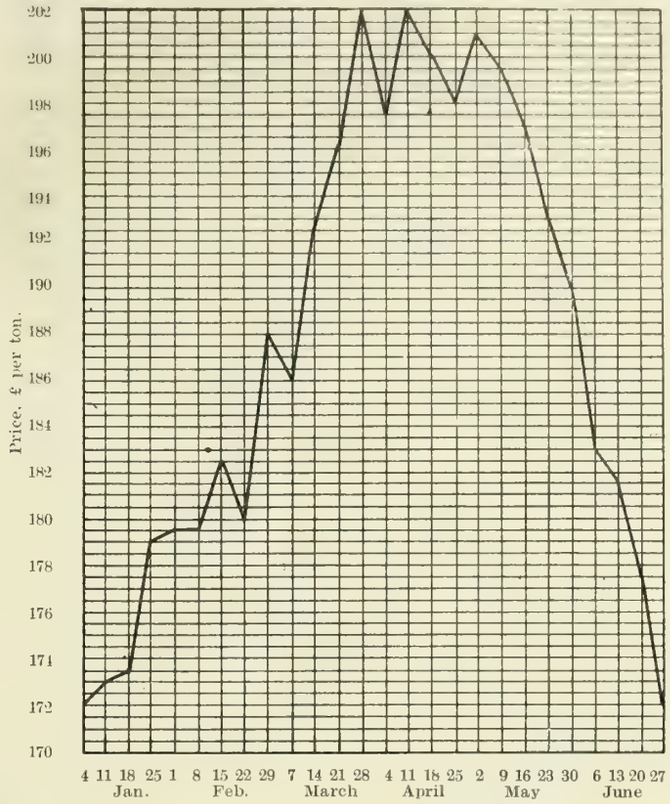
state, then add the tin, stirring the whole thoroughly with a graphite rod stirrer, and after previously heating the zinc, add the amount of zinc weighed out and stir thoroughly. Keep the pot covered with a graphite cover during the melting period. After adding the zinc allow the whole charge to come to a good melting heat, denoted by the play of zinc flames over the surface

Prices per ton of Copper. January to June, 1916.



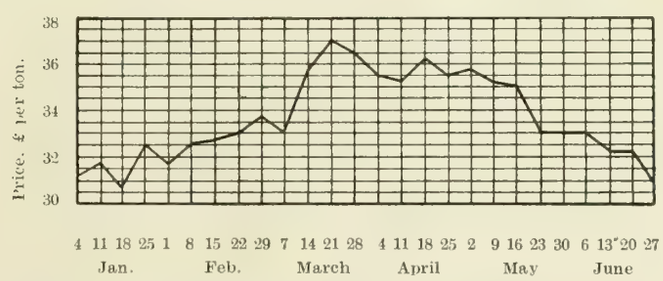
of the edge of the surface adjoining the crucible. Remove the pot from the fire and take the pouring temperature with a thermocouple. Pour the metal at any temperature between 1,120° C. and 1,270° C. (2,048° Fah. and 2,318° Fah.), but note the temperature at which the bars are poured. Use P-Pt Ir or P-Pt Rh (10 per cent.) thermocouple protected by a fused silica tube or an equivalent pyrometric method of determining the pouring temperature. When using platinum-rhodium couples add five tenths of the temperature recorded at the cold junction to temperature reading of millivoltmeter for the corrected pouring temperature, or 0·75 when using a platinum iridium couple.

Prices per ton of Block Tin. January to June, 1916.



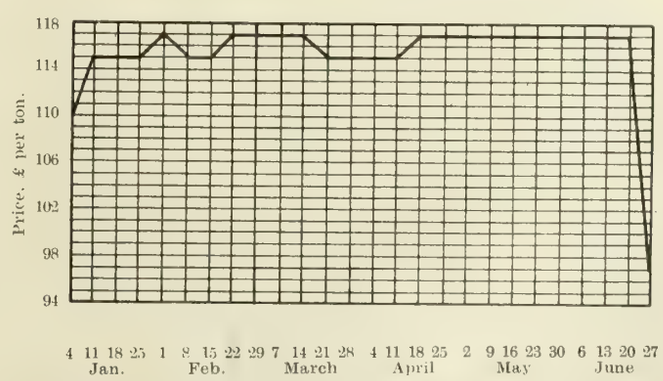
Use any good moulding sand equal to Albany No. 2. If green sand be used, the moisture content should not exceed 12 per cent. If dry sand be used, face the mould with a layer of sand equal in

Prices per ton of English Lead. January to June, 1916.



fineness to No. 00 Crescent sand, tempered with molasses water. When the mould is finished spray the moulds and runners and pouring gate with molasses water, and dry each flask before the

Prices of Zinc Sheets. January to June, 1916.



drying oven until the deepest pattern or feeding gate is completely dry. Allow the mould to cool to room temperature before being poured. Pick the vent holes with a fine needle in every one of the

bulb reservoir feeders. Put not less than three patterns of cast-to-size shape in each flask.

Skim the pot carefully before pouring and hold back dross and scoriae with the skimmer as much as possible before pouring. Pour steadily with a stream that will just about half fill the runner, and not large enough to choke the bore of the runner, so as to allow the bulk of the gases carried down by the pouring stream to escape upward through the space left in the runner and the pouring head. With every heat pour a wedge-shaped chill bar about 13in. long by 1½in. deep by 1½in. wide on top. Always pour the chill bar nearly flat and from the same end. Each chill will make three test bars. Always begin the numbering of the chill bars from the pouring end.

The size of the cast specimen in the rough should be 4¼in long, ⅞in. diam. at centre, and 13/16in. diam. at threaded ends. The size of the finished specimen should be, length over all, 4½in.; length of centre section, 2in. between gauge points; size of threaded ends, ¾in. diam. by 1in. long; length of each fillet ¼in., and diameter of centre section, 0·505in.

The foregoing specification with those of the United States navy are discussed as follows: The navy specifications call for a tensile strength of 30,000lbs. per square inch and an elongation of 15 per cent. A comparison of the tests of the zinc-bronze bars with these requirements are shown in the accompanying table.

How Zinc-bronze Bars meet Navy Specifications.

—	Percentage of bars meeting navy requirements.	Percentage of the remainder coming within 10 per cent. of same.	Percentage meeting only requirements of tensile strength.
Cast in sand—			
Cast-to-size shape	53·0	27·0	89·8
Cylindrical shape	52·8	27·7	73·3
Barrel shape	42·1	10·0	66·0
Cast-to-size shape annealed	100·0	..	..
Cast-to-size shape quenched	100·0	..	..
Cast in chill mould—			
Chill bar	4·5	1·0	87·5
Chill bar annealed	100·0	..	..

If one considers the tensile strength alone, it will be found that all of the test shapes and methods might be considered satisfactory, but the requirements for elongation are so rigid that only when the bar or the casting to which it refers is submitted to heat treatment is one able to meet these requirements; also this treatment restores the metal to its natural state and true condition and thus develop fully the physical properties of which it is capable.

If we study the effect of heat-treating test bars at the various temperatures of 500° C., 600° C., 700° C., and 800° C. (932° Fah., 1,112° Fah., 1,292° Fah., and 1,472° Fah.), for a period of 30 minutes, followed either by slow cooling in the muffle furnace to normal temperature or by quenching in water, it is found that, whereas the tensile strength is not greatly increased, the elongation and reduction of area are increased to a remarkable extent. The range of temperature from 700° C. to 800° C. (1,292° Fah. to 1,472° Fah.) appears to be the most favourable in securing the greatest increase in such properties.

In order to write a specification for the physical properties of a zinc-bronze that would not be too difficult of fulfilment, without detriment to the public service, it is necessary to consider what may be reasonably expected of such a metal alloy as zinc-bronze. It may readily be seen from the experimental work cited that a tensile strength of 30,000lbs. per square inch is not an unreasonable requirement. With reference to the elongation desired, it is found that 15 per cent. is difficult to obtain for specimens that represent small castings, because such castings, owing to their small sectional area, receive an initial chill which materially lowers the amount of possible elongation, and for such a casting the cast-to-size shape, on account of its relatively small section area, is naturally a representative type of test bar and should be chosen, but it is open for consideration whether 15 per cent. elongation for such a specimen is not too severe to be expected in the course of ordinary practice. In all probability 14 per cent. elongation and 13 per cent. reduction of area is all that may reasonably be expected for this alloy when the casting to be tested has a large sectional area in proportion to its mass. If the sample be poured within the normal range of temperature—that is, from 1,115° C. to 1,260° C. (2,039° Fah. to 2,300° Fah.)—the tensile strength of 30,000lbs. per square inch is not difficult to secure, and it is possible in a majority of cases to obtain an elongation of 15 per cent. and a reduction of area of 14 per cent., and for such castings a cylindrical shape may be chosen.

If a casting is to be chill cast, while it is very easy to secure a tensile strength of 30,000lbs. per square inch, it is, on the other hand, impossible to secure an elongation of 15 per cent.; in fact, an elongation of 4·5 per cent. would be a fair equivalent for such a casting. This is because the initial stress is so great as to almost completely destroy the property of elongation. Now, if a chill bar is submitted to a proper heat treatment, either annealing or annealing and quenching as described, it is quite possible to obtain and reasonable to expect an elongation of 15 per cent.

Hence from the foregoing considerations it is fair to conclude that for small castings a tensile strength of 30,000lbs. per square inch with an elongation in 2in. of 14 per cent. and a corresponding reduction of area of 13 per cent. may be required when using a cast-to-size shape test bar; for large castings, 30,000lbs. per square inch tensile strength, 15 per cent. elongation in 2in., reduction of area 14 per cent.; for chill castings, untreated, 30,000lbs. per square inch tensile strength, elongation 4·5 per cent., reduction of area 4 per cent.; and for chill castings, heat treated, the same tensile strength, an elongation of 15 per cent., and a reduction of area of 14 per cent.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

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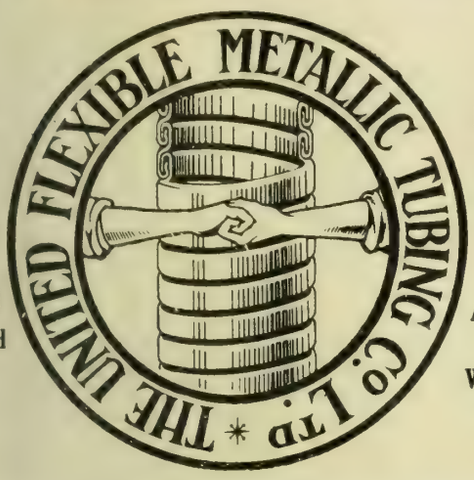

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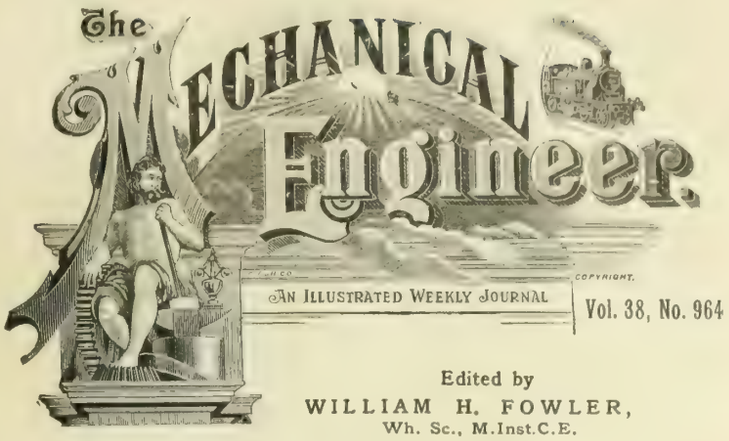

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WILLIAM H. FOWLER,
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Heat Transmission in Boiler Tubes.

SOME interesting details of experiments made by the Bureau of Mines at Washington in connection with the heat transmission through boiler tubes are given in a technical paper issued by the United States Department of the Interior. The details relate principally to the methods of measuring the temperature differences between the fire and the water side of the tubes by means of thermo-couples. The experiments were conducted with a water-tube boiler having tubes about 3½in. diam. Several of the thermo-couples were embedded in the bottom row of tubes at a point where the hot products of combustion enter them, while a couple was also placed in the highest row, where the gases left the boiler. A variety of experiments were made under different conditions, but the general conclusions arrived at only confirmed those deduced by previous observers, and now accepted as fairly expressing the relationship between the temperature of the gases and the water and the rate of heat transmission through the metal of the tube to the water within it. The value of the experiments consisted mainly in the extreme care taken to secure accurate observations of the temperature of the tube. These showed that the tube temperature was affected very little by the hot gases, but closely followed the temperature of the water in the tube. The chief resistance of the passage of heat appears to be very high from the hot gases to the gas side surface of the tube, and very low when this resistance is overcome from this surface to the boiler water. In other words, a boiler tube can transmit very easily the heat to the water once it has passed into the plate, and there is little chance of the plate overheating provided it is kept free from scale, oil, or other deposit, a condition, of course, that is very difficult to secure in practice, and in many cases seriously limits the speed at which the boiler can be worked. It is, however, the

fire side of the plate that opposes the greatest barrier to heat transmission and which probably offers the greatest opportunities for improvements in boiler design. The rate of heat entry into the plate depends, as Osborne Reynolds long ago pointed out, on the velocity of the gases over the plate surface, and the late Dr. Nicolson, it will be remembered, designed a boiler which under intense draught was capable of absorbing heat at a vastly greater speed than ordinary boiler practice, but his design failed to meet with adoption owing to difficulties in practical working. It is probable, however, that the future will witness advances in this direction, and a wider use of the principles of design he so strenuously advocated. The tendency is certainly in the direction of higher steam pressures, especially where turbines are employed. The Detroit Edison Company, for example, are considering plans for turbines to operate on a steam pressure of 500lbs. per square inch, and at the recent convention of the National Electric Light Association of America a contribution was presented by Mr. Robert Cramer outlining the problems which higher steam pressures involved, and in which he intimated that there were no difficulties at present in using pressures of the amount named, at least so far as boilers are concerned, makers of water-tube boilers being ready to turn them out as commercial apparatus provided orders are on a sufficiently large scale.

Boiler Explosions in 1914-15.

THE annual report on the working of the Boiler Explosions Act for the year ended June 30th, 1915, has just been issued. As usual it is a belated document, and only makes its appearance over 12 months after it is due. The returns presented are, however, satisfactory. It shows that the number of persons killed, 22, and the injured, 55, are below the respective averages for the 33 years since the Act came into force. Of the 61 explosions recorded the bulk were of a very minor character, and might be passed in many cases as little more than incidents of ordinary wear and tear, the whole of the 22 deaths reported being caused by eight explosions, of which five occurred on land and three on board ship. As contrasted with the toll of life and limb in other countries, it must be admitted that the enormous quantity of steam utilised for power in this country is generated and distributed with remarkable safety. During the year referred to three formal investigations were held, and references are made in the report to an important recommendation of the commissioner to boiler insurance and inspecting companies, viz., that such companies "should arrange as far as possible to vary the districts assigned to their inspectors, and that there should be a more careful supervision in the passing of the inspectors' reports and in the issue upon such reports of certificates of fitness for a given working pressure."

Books for British Prisoners Abroad.—Regimental Care Committees and relatives and friends of British prisoners of war will do them a good service by bringing to the notice of the interned, in their letters to them, the fact that, if they are desirous of carrying on serious reading, they can obtain, free of charge, educational books on almost any subject by writing to Mr. A. T. Davies, at the Board of Education, Whitehall, London, S.W. To facilitate the dispatch of parcels of books and, if possible, the organisation of an educational library in every camp, all applications for books should, as a rule, be sent through, or endorsed by, the senior or other responsible British officer or N.C.O. in the camp. Where for any reason (which should be stated in the application) this course is impracticable, requests from individual prisoners will as far as possible be acceded to.

THE JOHANNESBURG MUNICIPAL ELECTRIC POWER STATION.*

BY J. H. DOBSON, M.SC., M.I.MECH.E.

(*Concluded from page 498, Vol. XXXVII.*)

Turbo-alternators.—Owing to the barometer standing at approximately 24·75″ as compared with 30″ at sea level and the relatively high engine-room temperatures experienced in this country, for the same output and the same temperature rise, it is a wise policy to have electrical machinery about 30 per cent. bigger on the Rand than at sea level and in the home country. When working at full load and ·8 P.F. in an engine-room temperature of about 100° Fah. the alternators are sufficiently large to keep the temperature rise between 65° Fah. and 70° Fah.

The alternators connected to the first and second steam turbines were made by the Lahmeyer Electrical Company. Each stator consists of a substantial cast-iron shell provided with special air intake and outlet ducts. The coils are former wound in open slots, closed by means of suitable wedges. The active magnetic material of the stator consists of stampings of the best iron of high permeability insulated from each other by paper. The stator winding consists of heavy copper rods of rectangular section, 20 mm. high and 10 mm. thick, which have the insulation pressed on to the coils by hydraulic means. The thickness of the insulation round the rods is 3 mm. The end connections are simply flat strips of copper sweated on to the ends of the stator conductors and are securely held together by a large number of highly insulated supports mechanically strong enough to withstand the high magnetic forces in the event of short-circuiting. Each rotor is of exceedingly strong construction, the shaft and spider being formed of one solid shell forging. The active magnetic material is securely fastened to the spider and the 4-pole winding is of the salient pole type with copper strips lying flat in the slots and turned on edge at the ends of the rotor. The copper strip is secured in the slots by means of metal wedges and at the ends by means of steel winding covers shrunk on over an insulating layer of presspahn.

The third alternator is made by Siemens and embodies all the best points referred to above, but the construction of the rotor is perhaps a unique feature. It is of the cylindrical type, and the whole rotor body and shaft consist of one solid steel forging, the slots and axial ventilating ducts being accurately cut out by special milling tools. This construction gives it extreme solidity and strength, ensuring constancy of balance and obviating any risk of the component parts shifting due to centrifugal force. The outer bearing of each alternator is insulated to prevent any large current flowing through the main bearings due to any electromotive force set up in the shaft by varying magnetic reluctances in the phases of the alternator windings. The air gaps are relatively large, being $\frac{7}{8}$in. on one and 1in. on two of them.

Cooling Arrangements.—Each turbo-alternator is air cooled by means of special fans fitted on each end of the machine. The inlet of air in each case is through a special air box fitted with two layers of cocoanut matting to keep out dust and dirt and placed outside the engine-room so as to admit clean cool air to the alternators. The exit of the air from the alternators is a long air duct carried outside the engine-room in such a manner as to prevent the hot air from being drawn in at the air intake. In each case the air enters the alternators at the ends and is rejected in the centre of the machines.

Excitation.—The exciting current is led to each alternator through slip rings insulated from the main shaft by means of a mica collar, and each alternator is fitted with its own exciter on the continuation of the shaft. Separate exciters fit the conditions of the power station better than having separate exciting sets, for the simple reason that there are times of low load, during which time one turbine can supply all the requirements, and it is more economical to have the exciting direct on the end of the alternator shaft than separately driven. The voltage of the main alternating current busbars is kept constant by means of a Tyrrell regulator, which can be switched on to any of the machines that happen to be working. It is found that when more than one turbine is working any variation of the load is taken up by the one alternator to which is connected the Tyrrell voltage regulator.

* Abstract of paper read before the South African Institution of Engineers, and reproduced from the Journal of the Institution.

Working Results of the 3,000 kw. Turbo-Alternators.—The charts of the Lea recorder and the readings of the output in units recorded on the main switchboard from each alternator form ready means of checking the steam consumption per unit. The following is typical of numerous special tests that have been carried out for steam consumption per unit with a boiler pressure of 175lbs. per square inch at the stop valve, taken under actual working conditions for periods of about one hour :—

Load.	Units per hour.	Back pressure in lbs. per sq. in.	Lbs. of steam per unit superheated to 540° F.
Approximate 4/4 full load.....	3,100	1·28	15·146
" 3/4 "	2,177	0·985	15·195
" 2/4 "	1,527	0·866	16·01
" 1/4 "	829	0·714	17·46

When all the power required for auxiliaries is taken into account, the steam consumption per unit on full load is from 15·6lbs. to 15·8lbs. at a back pressure of approximately 1·1 lbs. per square inch, and from an analysis of the various losses in the steam turbine the blade efficiency is from 88 to 90 per cent.

The first turbine has been running for nearly five years, and its running has been perfect. Some six months ago, after four years' continuous running, the low-pressure blading showed signs of pitting, and it was decided to replace same, but before carrying out this decision some of the blading stripped and the work had to be done more quickly than anticipated. It can be safely stated that the turbine ran for a period of four years before it became necessary to replace any blades, and all but the low-pressure blading have not been touched and are still satisfactory. Experience has proved that it is best to replace blades when they show pitting rather than wait for their final destruction. The second turbine has been running since July, 1911. Before this machine was finally taken over from the contractors, four rows of the high-pressure blading stripped and did some damage to the drum of the rotor. The Council had to acknowledge lack of foresight and inaction on the part of the driver in attendance on the turbine, and it was decided that the Council and the contractors should each pay half towards the cost of the breakdown. Apart from this the machine has run excellently since its installation four years ago; but taking the experience on the first turbine into account, the blades at the low-pressure end were recently replaced. The third turbine was installed in August, 1913, and has run satisfactorily to date. Taken altogether, the running of the turbines has been satisfactory, and the Council up to the present has been spared the calamities that have befallen some of the turbine plants that have been installed on the Witwatersrand.

Comparative tests were made to ascertain the power absorbed in auxiliaries in Nos. 1 and 2 turbines, the first of which has a condensing plant fitted with the kinetic air and centrifugal pumping arrangements with steam jet, whilst No. 2 has the ordinary reciprocating Edwards air pumping arrangements. The result was distinctly favourable to the reciprocating air-pumping arrangements, but it was found to be due chiefly to the wrong adjustment of the steam jet. After experimenting for some considerable time a steam jet was designed which reduced the amount of circulating water required for a certain vacuum by more than 20 per cent., and the total power absorbed in each system is now practically the same. It is found in practice that where circulating water has to be cooled by means of cooling towers which take advantage of windage, a steam jet is of great value under certain conditions, and it has been decided to install steam jets in the air-extracting arrangements of both No. 2 and No. 3 turbines.

The alternators have been remarkably free from electrical faults; in fact, there has not been a single fault during the whole time the three sets of turbo-alternators have been running. This result is perhaps a testimony to the precaution of ensuring that the electrical portions were sufficiently large for this high altitude and the relatively high engine-room temperatures experienced in Johannesburg. There has been no trouble in connection with current flowing through the bearings due to the precaution of having the outer bearings of the alternators insulated. The curves of electrical pressure between the outer bearing and pedestal on the three machines may be of interest (see Fig. 1). The R.M.S. value of the bearing voltages were: No. 1 alternator, 13 volts; No. 2 alternator, 2 volts; No. 3 alternator, 3 volts.

Each of the above curves is alternating in character which is a practical demonstration of the theoretical deduction that the cause of the bearing currents is chiefly due to the joints in the stator. The third harmonics are present in the curves of No. 2 and No. 3 alternators. In the former the amplitude of the third harmonic is about 1½ times the amplitude of the main curve. A matter of special interest is that on No. 1 alternator the bearing voltage is very much greater than on Nos. 2 and 3. This will be understood when it is stated that the magnetic circuit of No. 1 alternator gave out a very loud noise. After tightening up the stator laminations and other investigations this nuisance still remained; and a process of elimination led to the conclusion that the seat of this disturbance was at the stator joints of the two halves of the stator. Tightening up as much as possible had no beneficial effect, but when a thin layer of hard paper was placed between the stator joints the noise was entirely eliminated. This, however, had the effect of increasing the reluctance of the magnetic circuit at these points, and as a result the voltage at the bearings is greater on No. 1 alternator than on the others.

Converting Plant and Balancing of the 3-wire Direct-current System.—The direct-current requirements are about 4,000 kw. for the lighting system and about 3,000 kw. for traction. There are 3,000 kw. of direct-current plant, viz., two 500 kw. and one 1,000 kw. ordinary 2-wire direct-current generators, and one 1,000 kw. 3-wire direct-current generator arranged with a static

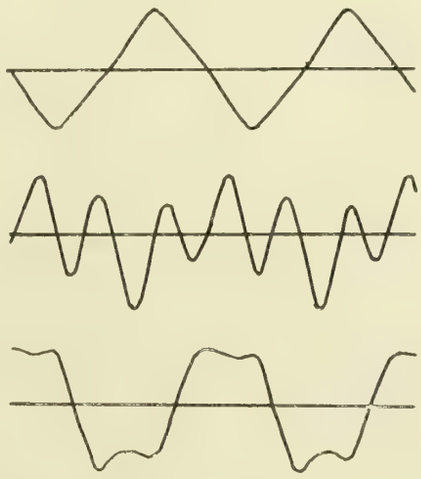


FIG. 1.

balancer. Each generator works as an ordinary shunt-wound machine when on lighting, and as a level compounded machine giving equality of voltage at all loads when on traction. The other direct-current plant consists of four motor converters, which also work as shunt-wound and compound machines when on lighting and traction respectively. The duty of the converting plant is to transform the 2-phase alternating current generated at 3,300 volts, 50 cycles, to: (*a*) 3-wire direct current at 460-520 volts, with necessary balancing arrangements for the 3-wire system of the light and power supply for the "inner" area; (*b*) direct current with compounding arrangements for the traction voltage, 500-600 volts.

The size of the converter units was chosen with particular reference to the traction and lighting loads at various periods of the day. Two 750 kw. and two 1,250 kw. units were installed and have been running for over four years.

—	750 kw Sets. r.p.m. 375.	1,250 kw. Sets. r.p.m. 273.
No. of poles on A.C. side	8	10
" " D.C. "	8	12
No. of commutating poles	8	No. 3—6 No. 4—12

Choice of Motor Converters. Electrical engineers in various parts of the world some four years ago were divided into two classes, the one adhering particularly to rotary converters and

the other adhering rigidly to motor converters. The claim of the adherents of the rotary converters, however, was that the rotary is as good as the motor converter, is less costly and more efficient than the motor converter. There was the well-founded prejudice about the satisfactory running of rotary converters on 50 cycles, especially when the requirements involved a large voltage variation, such as the duty required in the Municipal power station for lighting and traction requirements (460/600 volts).

Motor converters were chosen on account of their established reputation as being reliable machines and occupying a mean position with regard to capital expenditure and efficiencies of the motor generators and rotary converters. The principle of the motor converter is well known. At the moment of starting the frequency of the current in the rotor of the induction motor portion is of the same frequency as the alternating-current supply, whilst the frequency in the windings of the direct-current armature is zero, the frequency of the former decreasing and that of the latter increasing as the speed increases. It follows that there must be a speed at which the frequency in the two windings is equal and synchronism is attained.

Starting-up and Synchronising.—Only on two special occasions have the machines been used for the transformation of direct current to alternating current, but worked satisfactorily. The general requirement is from alternating current to direct current. Six of the 12 phases on the 1,250 kw. sets and three on the 750 kw. sets are connected through slip rings to an external starting resistance. The machine starts up as an ordinary induction motor, and the field at the continuous-current end gradually builds up. The notch on the starting resistance is marked "Synchronising," indicating that this resistance brings it to approximately half the speed of the rotating magnet field in the stator, the remainder of the operation being carried out with an auxiliary resistance for fine adjustment. Meantime the direct-current field is adjusted, and finally the synchronising volt-meter connected between the rotor winding and the direct-current winding indicates when synchronism is attained. The starting resistance is then short-circuited by the operation of a handle close to the slip rings, the rings are short-circuited, and all the windings on the rotor are then connected to one another. The synchronising of the machines is very simple, the whole operation not taking more than about two minutes.

Construction.—The motor converters are supported by three bearings, the bedplates being made in two halves bolted together. The alternating-current and direct-current armatures are rigidly coupled together, the electrical connections between the two portions being led through a hollow shaft. The stators are made in one piece, the active material being built up of laminations insulated by paper and slotted to receive the conductors. The laminations are clamped between heavy cast-iron end plates, with spacing discs at suitable intervals for efficient ventilation. The slots in the stator are almost closed and are lined with insulating tubes of micanite. The end connections are protected by cast-iron shields. The alternating-current rotors are built up of iron stampings assembled on a spider, with the ends of the phases led to the slip rings at one end and through the hollow shaft to the direct-current armatures at the other end. The field systems of the continuous-current ends consist of substantial iron castings split horizontally into halves carefully connected and bolted together. The field coils are former wound, tape insulated, and impregnated with varnish before being placed in position on the poles. They are held in position by laminated pole shoes, which in conjunction with the commutation poles ensure sparkless commutation. The direct-current armatures are built up of stampings assembled on a spider of rigid design, spaces being interposed at intervals to allow of free ventilation. The coils are former wound, and are placed in insulated slots.

Speed-limit Devices.—Speed-limit devices were called for in the specification in case the machines came out of synchronism and attempted to run up to the full speed of the rotating field of the stator. In practice these have been found unnecessary, as the large current taken on the alternating-current side under such circumstances brings out the circuit breaker.

Electrical Connections to Main Direct-current Busbars.—All the direct-current machines are connected either to the direct-current lighting mains or to the traction busbars through a triple-pole throw-over switch. When this throw-over switch is closed in the upward position the machines are connected to the lighting busbars as shunt generators, and the neutral points of the 3-wire generator and the motor generators are closed and connected to the neutral busbar by one operation, and is, by this arrangement, "fool proof" against leaving out the provision of the balancing arrangements. In the downward position the machines are connected to the traction busbar as compound generators with the necessary equaliser bar connections.

Working Results of Converting Plant.—The motor converters have now been running for about four years. The first three that were installed gave some trouble in the initial stages due to sparking, but the cause proved to be due to minor points connected with the adjustments of the machines and not to inherent faults in the type of plant. Particular attention was paid to the correct width and quality of direct-current brushes, correct magnetic centring of the revolving parts, and correct spacing of the direct-current brush arms, after which the commutation was greatly improved, and the running during the past four years has given general satisfaction. The fourth machine also gave trouble in the initial stages of operation owing to bad commutation, probably due to the higher harmonic currents in the direct-current armatures being of greater magnitude than the manufacturers anticipated. The difficulty was overcome by the insertion of damping devices, as is usually done on single-phase converters, and the running of this machine is now equally as satisfactory as the other three.

In general, it has been found that motor converters require much more minute adjustment than ordinary direct-current generators, but when once correctly adjusted the attention required is no greater than on any other type of direct-current plant. The doctor's bill has been relatively small. There have been two faults during the whole of their running, covering four years, the one consisting of a breakdown on the rotor of one of the larger sets soon after its installation, due almost certainly to damage in transport. The second fault occurred quite recently in the stator of one of the smaller machines, the insulation of one of the coils breaking down to frame.

Power Factor and Efficiencies.—The guaranteed efficiencies of the converters as shunt machines were :—

	1/4 F.	2/4 F.	3/4 F.	4/4 F.
750 kw. set	—	89	90·5	91
1,250 kw. set	82·75	89·5	91·0	91·5

The efficiencies as obtained in actual working, obtained by a large number of measurements of the input and output of power at the various loads, show that the guaranteed efficiencies were exceeded by about 1 per cent., and this is conformed by the measurement of the separate losses. The sizes of the converters are such that it is never necessary to work any of them below half-load, and the efficiency of transformation is thus never below 90 per cent. The power factor varies from ·7 to ·85 lagging when the converters are on lighting, and from ·98 leading to unity power factor when on traction.

Three-wire Balancing Arrangements.—One of the most important matters connected with a 3-wire lighting supply is the balancing of the voltages due to the inequalities of load on the two sides of the 3-wire system. The perfect provision for balancing in connection with the motor converters is a feature of the arrangement. All engineers will appreciate that if ordinary rotary balancers are suddenly thrown out of action through mechanical defects or by being called upon to cope with a sudden large out-of-balance load, enormous damage may be done to lamps, &c., on the distribution system by the excessive voltages which might arise on one side of the system when the balancing arrangements fail. Each of the motor converters installed in the Municipal Power Station is capable of dealing with an out-of-balance current of 15 per cent. with a difference of voltage between the two sides of the machine of 1·5 per cent. of the average voltage per side, the middle wire of the 3-wire system being connected to the middle or star point of the rotor windings through a terminal on the starting resistance which is connected to the short-circuited slip rings. In the case of the three machines having an equal number of commutating poles to main poles, the commutating pole circuit is divided up by fixing the windings alternately in the positive and negative mains. In the fourth

machine, having only half the number of commutating poles to main poles, there is an additional winding on the commutating poles, having half the number of turns as the main windings, and the current of the middle wire of the 3-wire system passes through this additional winding.

The method of balancing by means of the neutral points of the motor converters has the following advantages as compared with rotary balancers: (i.) It is more efficient, as the windings utilised for balancing are in circuit in any case. (ii.) It is safer, as it forms a permanent part of the converter unit and cannot drop out of action without bringing out the machine with it, this being preferable to doing damage to the different portions of the distribution system of high voltages. (iii.) It requires less attendance than rotary balancers, and it is impossible to start up without the balancing arrangement being attached to the busbars at the instant that the converter is put on the mains. (Attendants may forget to start up rotary gear.) (iv.) Converters provide a large capacity for dealing with out-of-balance currents. Thus with two 750 kw. sets and two 1,250 kw. sets working on a 3-wire system, 15 per cent. of 4,000 kw. is 600 kw. or about 1,200 amperes. To provide for such by means of rotary balancers would be very costly.

The use of rotary balancers has therefore been discarded, and normally the out-of-balance load can be kept within 200 amperes, and the converters are able to deal with it easily and the difference in voltage is practically nil.

Switchgear.—It is not intended that a description of the switchgear and the main switchboard should form part of this paper. It is the largest switchboard in South Africa, with four alternating-current generator panels, four direct-current generator panels, and four converter panels for the plant already described, and there are 22 direct-current traction feeder panels, 16 3-wire direct-current lighting feeder panels. 16 alternating-current single-phase feeder panels, and six alternating-current 2-phase feeder panels. All alternating-current panels are arranged in desk fashion. Unfortunately this paper is already long and does not admit of even a brief description of the board. The power for auxiliaries is supplied from a separate and independent section of the switchboard, and can be supplied with power from the main busbars or independently from the several units in the spare engine room. The station lighting can be given from a small steam generating set as and when required.

Concluding Remarks.—The following figures convey some idea of the growth of the system since 1909, and of the present dimensions of the electric-supply undertaking :—

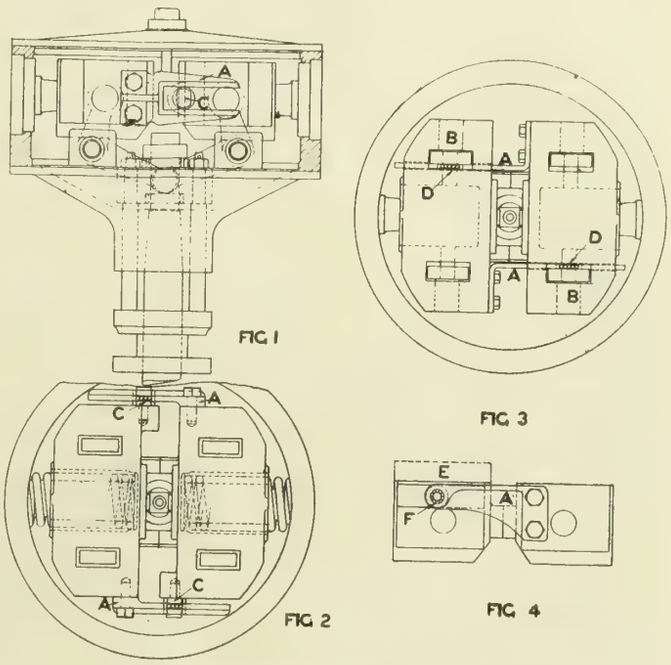
—	1909.	1915.
Total number of connections to mains....	5,720	16,091
Total number of meters on system	5,753	17,350
Total units generated	12,694,367	26,426,072
Maximum load (kw.)	5,400	10,800
Total number of street lamps.....	5,340	7,000

The monthly load factor, based on the maximum number of units generated in any one hour (usually on Saturday evenings), is approximately 30 per cent. The works costs are approximately ·5d. per unit measured by the actual units delivered to the direct-current traction, the 3-wire lighting, and to the alternating-current busbars. This includes a price of 4s. 6d. per 1,000 galls. at present paid for town water. The capital charges on the total power-station equipment is approximately ·22d. per unit, making a total cost of approximately ·72d. per unit generated. The selling prices vary from 6d. to ¾d. per unit.

The department is in a sound financial position, and a brief reference is given to a few statistics. An amount of £550,218 has been provided out of profits since 1903-4 (after wiping out losses owing to the gas-engine failure during the years 1906-7 and 1907-8). Of this amount £95,227 was utilised for capital moneys, and the remainder went to the relief of rates, either in assessment rate or direct appropriations in aid of rates. The annual amounts provided for the above purposes during the last few years has represented some 6 or 7 per cent. of the capital of the whole of the electric supply department, which is approximately £1,000,000 sterling, of which £286,000 belongs to the new steam station plant and buildings, £244,326 is held as an accumulated fund for the redemption of the loans, and there is a net amount of £127,698 still standing to the credit of the renewals fund.

HARTNELL'S CENTRIFUGAL GOVERNOR.

MR. WILSON HARTNELL, Aysgarth, Roundhay, Leeds, has recently patented a method of guiding and revolving the weights of centrifugal governors when they are pivoted to, or rest upon, rocking levers, so that the weights always maintain the same angular position in reference to any plane of rotation when at the same radial distance from the axis of revolution. The weights are coupled to a sliding sleeve on the spindle in any usual manner so as to move equal distances to or from the axis of revolution. Figs. 1 and 2 represent the side view and plan view of a centrifugal governor with the guiding arms on the outside of the weights. Fig. 3 represents a plan view with the guiding arms partly inside the weights. Fig. 4 represents a side view showing the arms resting in grooves on the opposite weight. The arms A are fixed at one end on each weight, which rest and slide on the weight diametrically opposite. These arms are slotted radially (see Figs. 1, 2, 3) and embrace a roller placed on an extension of the lever pin D of the opposite weight B, Fig. 3. If these slots are parallel to a plane of rotation, the weights must always be in the same angular position in respect to that plane at any radii, although the weights may rise and fall axially. By inclining or curving



HARTNELL'S CENTRIFUGAL GOVERNOR.

these slots the angular position of the weights can be varied, when required, for every variation of radial position. If it is not convenient for the slots to rest on the extended lever pins, special roller pins C (Figs. 1 and 2) may be fixed on the weights conveniently near the lever pins. This construction can be varied by putting slots on weights and placing the pin and rollers on the arms of the diametrical opposite weight F (Fig. 4).

The advantages of the arrangements described are that the centrifugal, centripetal, and gravitational forces can produce no tilting movement of the weights. Hence the lever pins can be located on the weights where most convenient to suit any requirements, such as to give the desired travel of the governor sleeve. The weights themselves, within limits, may be increased or decreased (see dotted line E, Fig. 4), to suit a variation of mean speed or governor power. The governor also may with safety be run in any required position, such as vertical, horizontal, or inverted.

TREATMENT OF FEED WATER FOR LOCOMOTIVE BOILERS.*

BY L. F. WILSON.

THE term "bad water" may mean nearly anything or nothing at all. Evil tendencies, incident to the use in locomotive boilers of all kinds of water, evidence themselves in three ways, viz., in incrustration, in corrosion, or in foaming sometimes all three

* Paper read before the Cincinnati Railway Club, May, 1916.

together, but luckily we do not usually find much scale in a water which has a natural foaming tendency, or foaming in a water which has a large percentage of incrustating solids. Without going too deeply into the chemistry of feed water, it is well for all motive-power men to know that, roughly speaking, the sulphates cause hard scale, the carbonates cause a mud precipitate, and alkali salts cause foaming, if in predominancy. Therefore a glance at a carefully prepared analysis will serve to determine what may be expected to happen when the water is evaporated. Sulphates precipitate only at a boiler temperature corresponding to 60lbs. or 70lbs. pressure. Carbonates precipitate at boiling temperature (212°). This explains why low-pressure boilers do not have serious scale troubles.

The direct results of a coating of hard scale in a boiler are high boiler maintenance cost, higher fuel cost, and failures on account of leaking. Foaming has even more direct results in cut cylinders, clogged-up superheaters, and reduced pulling capacity to the point of failure. Corrosion goes with the sulphate scale. It is the rankest fallacy to advance the theory that a coating of scale will protect a boiler from pitting. Corrosive action goes on under a sulphate scale by the release of acid incident to the high temperature, and the iron is turned into red oxide, familiarly known as rust. Due to the unstable nature of the resulting sulphate of iron, the acid is continuously liberated to attack the iron, leaving the oxide layer behind, as can be readily noted under a high temperature, high-pressure sulphate scale. It occurs in "pits" simply on account of lack of homogeneity of the metal —some portions lending themselves more readily to acid action.

The treatment of boiler feed water may be pursued by any one of three methods, which may be termed for the purpose of this paper "external treatment," "semi-internal treatment," and "internal treatment."

By "external treatment" is meant the wayside plant or mechanical water softener. In the treatment of boiler feed waters by this means, on a railway, it is customary to locate water-treating plants at points where large amounts of badly incrustating waters are taken. Assuming, of course, that the proper chemical reagents are used, this method is ideal, under certain conditions, and has to its advantage a feature which appeals to steam engineers, in that it deposits the incrustating solids before the water is taken into the locomotive tenders; but its disadvantages are very evident, after some little thought.

We will assume that a division of one of our railways has water stations at five points—A, B, C, D, and E. It is brought to the attention of those in authority that the water at station C is scaling up the boilers very badly, and after due consideration a water-treatment plant is located at C, and it goes into operation. It then becomes evident that now the waters at B and D are very bad, although by comparison they were not considered so bad as that of C. It is also discovered that there is little improvement in the conditions of the boilers, because of the fact that there is only a small percentage of water taken on the division which has been treated. The officers are then up against the proposition of treating the rest of the waters. Now, each treating plant costs several thousand dollars, and they must be operated by men who must necessarily be on the pay roll and who must give their time to the operation of the plants. In lieu of this, they can, of course, get along with the slightly better results which they have obtained. It must be remembered that this is only one division, and in these times of stringency in the railway treasuries these officers are going to have trouble in securing the necessary appropriations. We must also remember that the chemicals which are used in these treating plants cost nearly as much, and sometimes more, than those used in other methods of treating.

In the above we are assuming that the water which has been treated by these plants is perfect boiler water. Unfortunately this is not always a fact; it is very frequently the case that the water which is delivered thus has acquired an evil tendency which it did not have in its raw state, viz., foaming. This means that the semi-internal treatment must be used after all. That is, we must hold this water down in the boiler by the use of some anti-foaming compound. The reason for this foaming tendency can be explained easily. The usual treatment, used to throw down the scale-forming impurities, is sodium carbonate (soda ash). A reaction in the boiler splits up the calcium sulphate and the sodium carbonate, and recombines them as sodium sulphate and calcium carbonate, the latter being precipitated as mud, and the former remaining in solution. W. A. Pownell, of the Wabash, is authority for the statement that a boiler will be in a foaming condition when the sodium sulphate and other sodium salts have reached a concentration of 2,000 or more parts per million. This concentration is increasing steadily as the water is evaporated and used as steam. It must be reduced by changing the water periodically or constantly according to circumstances. A good anti-foaming compound will allow of a far higher concentration, and is therefore an economy in this method of treatment, as the enormous waste of constant water change is reduced to nearly zero.

By the term "semi-internal" is meant the addition of a boiler compound to the water in the tender tank. This method of treatment has been in use on many railways of the Continent for a great many years. It resembles in effect the method just explained, and was first used systematically about 30 years ago. The treatment consisted in the use of our old friend sodium carbonate, commonly known as soda-ash. The use of soda-ash therefore is of long standing. Its purpose is to throw down the incrustating solids only. In waters which are not heavy in incrustating solids, the beneficial results from the use of soda-ash or a good proprietary anti-scaling compound are so evident as to be undeniable. However, its very method of use is against it. Enginemen do not directly benefit by the use of a material which is given to them to use, which has for its sole purpose the decrease in boiler maintenance cost. The officers of the railways who are responsible for its use give instructions as to the amount to be placed in each tank of water. This amount is usually figured large enough to throw out of solution, by chemical combination, the sulphates which form scale. Unfortunately, where these sulphates are in large proportions a dose of compound which will take care of them is so large as to result in a concentration in the boiler which results in foaming, thus striking the engineman between the eyes. He is responsible for getting his train over the road, but he is not responsible for the scale in the boiler. What is the logical solution which occurs in the brain of this engineman? The soda-ash will do no harm on the right of way or in the firebox; the fireman can take his choice, and nobody is the wiser. There are many treatments which are designed to be used in just the same way as the above, and while the results from same may be good to a certain extent, the disadvantages as above detailed apply to them all.

With respect to the use of compounds which are prescribed for certain water analysis and used by any method, they may work with beneficial results where one kind of water is used (that for which the compound is prescribed); but it does not seem logical to assume that for locomotive boilers this could be practical. Some switch engines, it is true, may operate constantly in one water, and such treatment would work successfully. We are, however, interested in eliminating the evil effect of bad water out on the line. A passenger engine may go over the division on three tanks of water. A freight engine may go over the same division on five tanks of water, more or less. Each day these supplies are taken into the tender in different proportions, therefore each day the average analysis differs. Is there a chemist who would assume to find the correct reagents under such conditions? Yet these are the normal conditions.

So far as the writer is aware, the first use of a semi-internal treatment or, in fact, the first attempt to treat bad boiler-feed water on any large railway, which attempt later led to general use of the treatment on that road, was initiated on the Chicago, Milwaukee, and St. Paul, in 1879. A machinist at the North Milwaukee shops compounded soda-ash, tannin extract, and sorghum, and used the combination in a few boilers with fairly good results. Later this material was mixed at Milwaukee and shipped to different provision terminals. By 1890 it had been discovered that the commercial soda-ash alone did all that the compound medicine had been doing, and it was thereafter shipped without mixing, for general application to the tender tanks.

In those days enginemen had the same prejudices that many of them evidence to-day, varying in effect as their prerogatives were not so limited. They objected to soda-ash, in that they could not see its benefit, and it caused foaming. The result was that the required amount for a trip had to be placed in the tenders at the terminal, and this large dose frequently did cause more than imaginary foaming. Some of the engineers took

readily to the new order and consistently carried out instructions with the result that their boilers required far less maintenance expense and the foaming bugbear lost in importance.

Still, down through the years to the present time, the objections to this method of using soda-ash have held good, and with the advent of larger power and pooled engines, the only incentive which the engineman had to use soda-ash in furtherance of his selfish interests, has disappeared. Close supervision can only slightly better the conditions, not cure them. Moreover, he who would supervise the consistent use of soda-ash must be prepared to offset the evil tendency to foam, given the water in the boiler by this system. He must blow out the concentrated water and replace it by raw water from the tank. This can be done systematically or spasmodically, but it must be done if water heavy in incrustating solids is to be kept within bounds after complete treatment. Either method of blowing involves the loss of fuel and water, and reduces boiler efficiency. Water which has been raised to the temperature of steam at a pressure of 200lbs. is pretty valuable material, and its heat units should be used in the cylinders and not to paint the right-of-way fences.

What is more natural than that we turn to a method of treatment which, while removing from the engine crew all responsibility and knowledge in the matter, still produces far better results than does this method, and which does not cause foaming and costs less than other method?

By the term "internal treatment" is meant a treatment applied to the boiler direct. Since the boiler must be opened at stated intervals for washouts or, in unusual cases, for running repairs, the application of a treatment placed directly in the boiler may be done at the periods when the boiler is opened for washouts or for repairs. Since any chemical reaction incident to the use of such a treatment must take place as rapidly as the reagents are brought into touch with their chemical affinities, and since the locomotives will probably operate on the average of 10 days between washout periods, it is evident that something other than ordinary chemical reaction must be depended upon for satisfactory results by this method.

The use of mercury has been made practical by a process in its treatment which involves heating and the separation of raw mercury into fine particles, and the addition of a carrying compound which has a primary chemical action in the boilers. It is necessary, however, for the reason just given, to depend on the mechanical action of the mercury, which is a peculiar one, and one which deserves explanation.

It is noted that the boilers which have been treated by this method are coated, so far as their heating surfaces are concerned, with a black film, sometimes designated as an amalgam but, more properly, simply as a "film." This film, however, does not form except the old adhering scale has first been thrown down, by the very process incident to the formation of the film. The surface film on the heating surface is formed only while under pressure and subject to heat. An oxidisation of the mercury which, in connection with the iron, cleaned by emulsified kerosene used in the preparation, and in the presence of a powerful alkali salt, forms this film under scale which may have accumulated, forcing it off by expansive action. This surface coating furnishes a protection against either acid or galvanic action. It appears to stand a sulphuric-acid test perfectly, and for this reason pitting troubles are reduced by its use.

This material is put up in stick form about 16in. to 18in. long and 1in. square, and weighing about 1lb. each, and is placed in the boilers through the washout plugs after the locomotives have been washed, making it a round-house proposition instead of being looked after by the engine crews, thus involving the services of one man for perhaps 150 engines, rather than those of 150 enginemen.

The carrying composition, after the boilers have been filled up, gradually dissolves, liberating the infinitesimal particles of mercury, too insufficient in mass to be much affected by gravity. These are carried into circulation all over the boiler until a lodgment is effected, probably in some broken edge of a piece of scale. Naturally every section of broken edge of scale on the boiler plate or tubes is somewhat loose, possibly owing to superior expansion of metal, and is to some extent free from the plate and tubes. Into this crevice a particle or many particles are hurled by the force of circulation, and mechanical exfoliation of the scale is effected. As soon as a particle has been hurled or has insinuated itself into the broken edge, the sudden expansion of the mercury, due to the superior heat of the plate or tube, may have something to do with detaching the hard deposit. Also the fact that the water following the mercury, and meeting the greater heat through the superior conductivity of the mercury, is put into such a rapid state of ebullition that the globules of steam rapidly arise, may have something to do with the detaching of the scale, or it may be the concerted action of both the mercury and water.

An important feature connected with the use of this treatment is the possibility of making a reduction in frequency of boiler washouts. Its effect upon the sludge and mud is to make it very slippery and fine in character, thus robbing the mud of its power to stick to the heating surface and bake, which often causes a mud-burn. This change in character of the mud is very important as it also makes it possible to blow out of the blow-off cocks a very much greater amount of solid matter than formerly. It will be readily seen that under these circumstances as frequent washouts as formerly are not needed, the reduction being from 50 per cent. on some roads to as high as 80 per cent. on others. Since boiler washing is responsible for a considerable amount of upkeep expense on locomotives, besides the valuable time it requires, this represents a very considerable saving. In fact, the cost of this treatment is being saved, and more than saved on the majority of engines now under treatment, by the reduction in the number of times engines are washed per month. This is a very important fact, and it will be seen that if the cost of this treatment can be saved by a safe reduction in the number of washouts, all the other savings resulting from its use—greater boiler efficiency, less staybolt and flue leakage, longer firebox and flue life, greater reliability of the power, &c. –are clear profit.

One of the results of the early direction of attention to methods of combating bad water conditions was the discovery that close adherence to carefully conceived rules in the washing of boilers would do wonders in reducing maintenance cost as well as fuel bills. Regardless of whether or not there is any treatment, boilers must be washed more or less frequently. A thorough job done according to a proper system costs little or no more than a haphazard one, and the good results of the former are too evident for argument. Boilers are washed more or less frequently as conditions require. On a great many roads the mileage which can be made between washouts is determined solely by the conditions of the water with respect to foaming. In most cases, in such localities, the obviation of foaming troubles automatically reduces the washouts by half or even more.

If foaming is caused by concentration of soda-ash used as a treatment by itself, or contained in some proprietary compound, then the logical thing to do it is change the treatment. It might be stated parenthetically, the mercury treatment abovementioned does not cause foaming. If the foaming is caused by suspended matter in the water as taken from its sources, then the use of a good anti-foaming compound is a source of great economy. It blankets the water in the boiler, holding it down under surprisingly severe conditions. It is easy to handle, and its use is a matter of great interest to enginemen, as it reduces their troubles instantly. There is no deleterious after effect such as is the case with crude oil. After it has performed its function it disappears from the boiler to the last particle.

Anti-foaming compound should be mixed with the water in the tender tanks, not fed through the injector direct. The proportions required then can be maintained and the most efficient service secured. Whereas, direct feeding is sure to result in larger quantities being used and inconsistent results being obtained. Anti-foaming compound should be checked out to engine crews in the same manner as is customary with valve oil. There is no good reason for the indiscriminate handling sometimes found. A minimum figure is obtained by test, and then the allowance should be made slightly larger than this figure to meet unusual conditions. If its use is systematic, there is a simplicity about the treatment which has its appeal. There is never any difficulty in getting engine crews to use anti-foaming compound, but there is sometimes difficulty in keeping the men from using too much. This does no harm to the boilers, but it increases the expense of treatment, and there is every incentive for close allowance in this compound that there is in the use of any other class of supplies.

THE EDUCATION OF ENGINEERS.

A SUB-COMMITTEE appointed by the Council for Organising British Engineering Industry, consisting of Mr. A. P. M. Fleming, of the British Westinghouse Company, Mr. J. C. Maxwell Garnett, Dean of the Faculty of Technology in the University of Manchester, and Mr. Miles Walker, Professor of Electrical Engineering in the Manchester School of Technology, has just issued a report on Engineering Education and Research, of which the following is a summary. The report recommends:—

(1) The organisation of British engineering industry, by the federation of British manufacturing engineers, for purposes which include education and research. Such a federation should co-operate with governing bodies of schools and colleges as well as with education authorities in providing a satisfactory system for educating engineers; with universities and colleges in testing and research; and with the Government in conducting a central research institution specially equipped for investigations with which existing research laboratories are unable to cope.

(2) The co-ordination of the existing means for educating engineers and, in particular, the provision of an adequate and more uniform system of scholarships. To this end, the number of local education authorities for the highest education should be reduced, correspondingly larger areas being assigned to each.

We have throughout had before us the need for applying to the education of engineers the same principle of continuity which is familiar in every branch of physical science. In accordance with this principle, we consider that the last two or three years of every person's whole-time education should have the specific aim of preparing him for his particular walk in life, so far as that can be foreseen. We are not asking for purely vocational training, and we do not suggest that during these last two or three years education should be unduly specialised. Our desire is rather to see a coherent curriculum in which every subject is linked to every other because they are all taught in close relation to the student's future activities, both vocational and social.

(3) That a large number of junior technical schools be established for the education between 12 and 15 of boys who intend to become apprenticed to engineering trades.

(4) That all apprentices under 18 years of age be required to attend part-time classes for, say, eight hours a week during works hours; but that this be subject to certain exceptions in the case of young people who continued in attendance at secondary or junior technical schools up to at least 15 years of age.

(5) That the instruction given to trade apprentices in these part-time classes be reformed so as to relate it more closely to the apprentices' every-day work and so as to include what are known as citizenship subjects, for example, economic history; and that, where a sufficient number of apprentices is employed by the same firm, such classes to be conducted in that firm's own works and by the works staff.

(6) That the specific education given to future members of the highly-trained staff be provided in a university or college of university rank for the majority who should be enabled to continue their studies up to 21 or 22 years of age; and in a senior technical school for the minority who may have to enter engineering works at 18.

(7) That boys who are to study engineering in a University should carry their study of mathematics and physical science to a higher stage before leaving school; and that, in general, the education of a boy at school, instead of being entrusted—as in some modern secondary schools—to six or seven specialist teachers whose business it is to advance his knowledge of a similar number of separate subjects to a uniform level of mediocrity, should be in the hands of a succession of form masters, who, knowing their boys well, may exercise a profound influence upon their characters and carry to a high level their studies in a more coherent curriculum.

(8) That the conditions for admission to universities should be reconsidered and rendered more uniform as between different universities and less uniform as between different faculties and different honours schools in the same university; and that, in the interest of candidates of mature age and of other candidates approaching the university otherwise than through the normal avenue of the secondary school, university entrance tests should be distinguished from secondary school examinations.

(9) The reform of university teaching in certain important respects, notably by a reduction in the number of lectures.

(10) That the completion of a three years' university course in engineering should entitle students to no more than the B.A. degree; and that, until candidates have added works experience to academic training, they should not receive technical degrees — such as Bachelor of Engineering or Bachelor of Technical Science—which might then serve as professional qualifications.

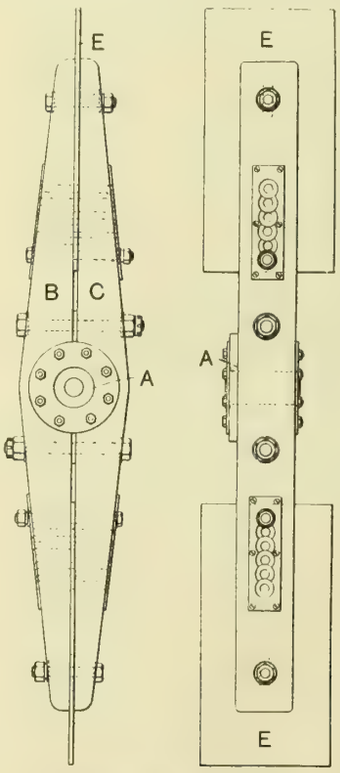
(11) That any time spent in works between school and college should not be unduly prolonged.

(12) That university teachers be encouraged to undertake research on behalf of, and in co-operation with, manufacturing firms; and that additional Government grants be paid to universities and colleges with this end in view.

(13) That, by the establishment of such an association of manufacturing engineers as we have advocated and by other means, the volume of research work carried out in connection with the British engineering industry be greatly increased; and that provision be made for this increase in the volume of research by fully utilising and extending the facilities already available in universities and colleges, as well as in the works of private firms, and also by establishing a central research laboratory for investigations that cannot be carried out elsewhere.

WALKER'S FAN DYNAMOMETER.

WE illustrate herewith an absorption dynamometer, in which the power is absorbed by the resistance of vanes revolving in air in a similar manner to that of a ventilating fan, the invention of Mr. Wm. G. Walker, 2, Emery Hill Street, Westminster, London, S.W. The bush A, in which the spindle of the motor is fixed, is gripped between the central portion of the jaws B C by means of bolts passing therethrough, and E are the vanes gripped at the opposite ends of the jaws by means of bolts. These bolts pass through longitudinal slots, formed in the vanes E and jaws B C. A series of slots are formed through the two jaws and at each side of the centre thereof and are spaced at a specified distance from each other, so that the vanes can be moved radially either inwards or outwards a specified amount. Similarly slots are formed in the vanes, but of a different pitch to those of the jaws, so that the vanes can be moved a distance less than the pitch of the slots in the jaws. Any desired radial adjustment may be obtained depending on the respective pitch of jaws and vanes. The dynamometer is so calibrated that the horse-power is known for certain sized vanes fixed at certain positions revolving at any speed. For example, suppose it is required to obtain the horse-power of an electric or petrol motor when running at a certain speed of revolution, the dynamometer is screwed to the spindle or shaft of the motor, and the vanes are adjusted to such a radial position so as to cause the motor to run at the required speed when under load. Knowing the speed of the dynamometer and the position and size of the vanes, the horse-power can immediately be ascertained from the calibrated results. The larger the vanes or the greater their radial distance, the greater will be the power necessary to revolve the dynamometer; the horse-power also increases with the speed of rotation.



WALKER'S FAN DYNAMOMETER.

DESIGN OF AN IDEAL THRUST BLOCK.*

BY C. P. TANNER.

In propelling a ship through the water, the propeller exerts a certain thrust on the water astern of the ship and, of course, by Newton's Third Law, the water exerts an equal and opposite thrust on the propeller. This thrust is transmitted along the line of shafting to the engines. In an ordinary reciprocating engine, the thrust would have to be taken up by the crank webs bearing against the main bearings unless other means were taken to receive this. To effect this a thrust shaft and block is placed between the engines and the propeller. In smaller engines the thrust shaft is made integral with the crankshaft, but this is unsatisfactory, and now is very rarely carried out. The method that is almost universal now is to make a separate shaft for the thrust shaft, and place it just aft of the crankshaft.

The thrust shaft must, of course, be designed to take the necessary torque exerted by the propeller as well as to take up the thrust. The diameter of the shaft is found from Lloyd's or Bureau Veritas rules, and is usually the same size as, or a little smaller than, the diameter of the crankshaft. It is also a little larger than those of the tunnel shafts, as if the thrust shaft breaks between any of its collars, it makes a repair somewhat difficult.

One of the first considerations is the number of collars to be employed to take up the thrust. Obviously, large collars will be less complicated, since there is a certain definite area to be used to take the thrust, and hence very few collars need be used if each is large. There are, however, several disadvantages to large collars. Forging is made difficult and also with a large diameter the inside of the shaft may contain flaws. Again, the peripheral speed of the collars is high, and this makes lubrication difficult, and increases the resistance due to friction.

The shaft is usually of mild steel, and should be carefully forged in one direction, and not half in one direction and half in the other, as this introduces a weakness in the shaft. In some cases 3 to 4 per cent. of nickel is added, and this gives a stronger shaft. All the advantages lie with a shaft having a large number of small collars, except the fact that it is very complicated. In calculating the dimensions of the various parts of the shaft and the block, the formulæ used are largely empirical although theoretical formulæ can be used to a certain extent.

From elementary mechanics we have :—

$$\text{Work done} = \text{force} \times \text{distance}.$$

Thus we get

$$\text{Effective horse-power} = \frac{\text{Thrust (in lbs)} \times \text{Speed (feet per min.)}}{33{,}000}$$

From this we have

$$\text{Thrust} = \frac{\text{E.H.P.}}{\text{Speed.}} \quad 33{,}000$$

The effective horse-power bears some definite ratio to the indicated horse-power, depending on the mechanical efficiency of the engine and bearings. The usual ratio may be taken as

$$\frac{\text{E.H.P.}}{\text{I.H.P.}} \doteqdot \cdot 77 \text{ for best high-speed engines.}$$

$$\doteqdot \cdot 68 \text{ for merchant boats.}$$

$$\doteqdot \cdot 80 \text{ for turbines.}$$

Thus we get

$$\text{Thrust} = \frac{\text{I.H.P.}}{\text{S.}} \cdot y \cdot 33{,}000 \text{ where } y = \text{mechanical efficiency.}$$

Hence we see that

$$\text{Thrust} = \frac{\text{I.H.P.}}{\text{S.}}$$

This thrust is usually called the mean normal thrust. It is clear that the thrust is excessive when the speed is slow, *i.e.*, when the ship is starting, or towing, or going against a strong head wind. Thus, although we have the mean normal thrust to base our calculations on, the shaft must be designed to take up the maximum stress, which occurs when starting or towing. There are various formulæ available. One which gives the area directly and with a fair degree of accuracy is

Bearing surface of collars in square inches $\cdot 6$ I.H.P.
i.e., 0·6 sq. in. for each I.H.P. developed.

A better way is to take a certain allowable pressure on the working bearings. Good values for these pressures are

50lbs. to 80lbs. per square inch for mercantile marine.
80lbs. to 100lbs. per square inch for naval.

A rough rule for finding the number of collars to be used is given by

1 collar up to 5in. diam. of shaft and an extra collar for every 1·8in. diam. ;

or

$$N = 1 + \frac{d \quad 5}{1 \cdot 8} \text{ for mercantile marine,}$$

and

$$N = 1 + \frac{d - 5}{1 \cdot 25} \text{ for naval and express.}$$

The diameter of the shaft, as stated before, is found from Lloyd's rules. Hence we have to find the diameter of the collar.

$$\text{Total bearing area } A = \frac{\pi}{4}(D^2 - d^2) \cdot N \text{ square inches,}$$

where D diameter of collar, d diameter of shaft, N number of collars.

$$\text{Total thrust} = \text{total area} \times \text{allowable pressure.}$$

$$T = A \times P.$$

$$= P \quad \frac{\pi}{4} \quad N\,(D^2 - d^2).$$

From which D can be found.

In practice the rule for the thickness of the collars is given by

$$T = 0 \cdot 4\,(D - d).$$

The space between the collars is found by :—

(1) With rings of solid brass $T = 0 \cdot 4\,(D - d)$.

(2) With rings of cast iron lined with brass or white metal $T \quad 0 \cdot 75\,(D - d)$.

(3) With rings of cast iron, hollow to allow for water circulation $T \quad (D - d)$.

Another rule for giving the pressure on a thrust bearing is

$$\text{Pressure in pounds per square inch} = \frac{800}{\sqrt{R\,d + 100}}$$

where R revs. per minute, d = diam. of shaft in feet.

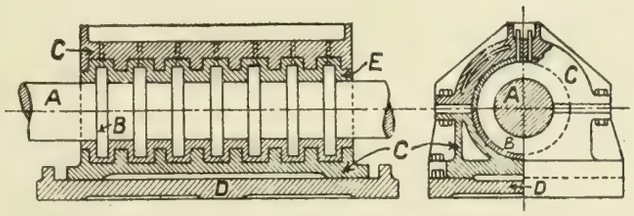


FIG. 1. SOLID THRUST BLOCK.

A. Steel Thrust Shaft. B. Collars on Shaft. C. Cast-iron Base Block and Cover, bolted to seating D. D. Cast-iron Seating bolted to ship's framing. E. White Metal Lining, cast in Base Block and Cover.

The thrust shaft and block are usually placed next to the crankshaft inside the engine-room if possible, so as to permit inspection of the block by the engineer in charge. The shaft is supported at each end by a pillow block so as to prevent any vibration which would cause an inequality of pressure on the thrust bearings.

There are three types of thrust blocks in use. Type I. shown in Fig. 1 consists of a cast-iron base block and cover, the division being horizontal. Rectangular grooves are turned in these, in which brass thrust rings are fitted. The rings are scraped to make a good fit with the collars on the shaft, and small radial oil grooves are cut in the former. Since, if this block were to heat, it would necessitate the stopping of the engine and the removal of the thrust shaft or the block, in the event of a serious heating and damage to one or more of the collars. The block is not generally constructed to admit of slipping it out by dropping sufficiently to clear the shaft, so that the disconnecting of the shaft is necessary as a rule before the block can be got out. Both the cover and base of the block are water cooled, but even with this the block is unsatisfactory, and is rarely used now.

For large engines Type II., the horse-shoe type, Fig. 2, is

* Prize essay presented to the Institute of Marine Engineers.

universal. It consists of a cast-iron bed, cast so as to provide a bath for lubricant, in which the shaft runs partially immersed. Cast iron shoes, hollow to permit of water circulation, and lined on each face with white metal, rest in position between the collars as shown. A fine-threaded screw goes on each side of the shaft down the whole length of the block, and gun-metal nuts on these hold the shoes in position.

The water service, not shown in the sketch, is arranged so that each shoe has a separately controlled supply of water. Hence the temperature of the whole block can be equalised, and this is conducive to smooth running. The bearings at each end have stuffing-boxes, so that the oil can rise above the bottom of the shaft, and usually immerses half the shaft. This oil, in many cases, is cooled by small water tubes passing starboard to port, through the oil bath. The cooling surface need not be large if

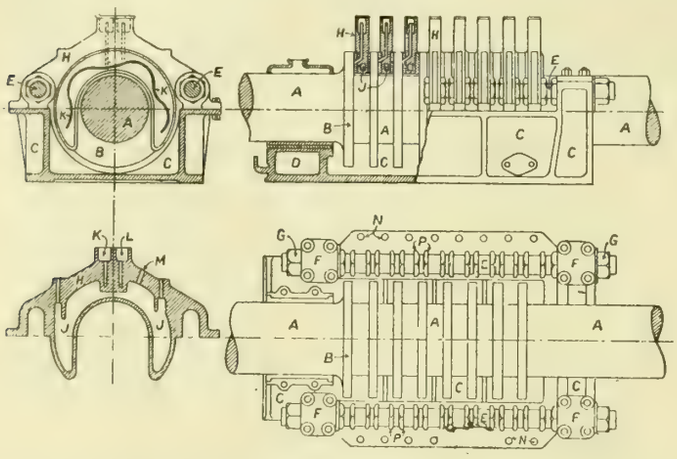


FIG. 2.—HORSESHOE THRUST BLOCK WITH INTERNAL WATER SERVICE.

A. Steel Thrust Shaft. B. Collars on Shaft. C. Cast-iron Frame, securely bolted to ship's framing, which takes thrust. D. Part of C, which takes the plummer block at after end of Thrust Shaft. E. Steel Screwed Thrust Bars secured to framing C. G. Thick Phosphor Bronze Nuts to take up thrust Often wrought iron. H. Horse-shoe Thrust Rings, lined with white metal on both sides next Collars on Shaft. J. Hollow space for water circulation. K. Oil Ways and Groove for ahead Thrust in white metal. L. Oil Way for astern Thrust. M. Air Outlet, fitted with a cock, from water service. N. Bolt Holes for holding down each shoe to frame. P. Phosphor Bronze Nuts for adjustment of thrust shoes independently.

the shoes are water cooled, as most of the heat generated by the friction is carried away by the water service through the shoes. Since the shoes are of the horse-shoe type, the centre of pressure of the bearing area is above the centre of the shaft. The thrust screws are, however, arranged so that they are on the same level as the centre of pressure, and thus the shoes bear evenly against the collar.

The chief advantage of this type is the fact that each shoe can be adjusted independently of the rest. Also if one shoe "fires up," it can be removed and replaced without stopping the engine. It also entails less spare gear. Lubrication is greatly assisted by the oil bath, and the oil grooves are cut in a special manner as shown. The chief difficulty in lubrication is due to the fact that the centrifugal action of the collars tends to throw the oil out immediately. Also there is no real point of "no pressure" at which to introduce the lubricant as in an ordinary journal bearing.

A third type is due to Mr. Seaton. This is similar in general construction to Type I., but the division of the two halves is vertical and not horizontal. This enables the block to be examined without removal of the shaft, as the two halves are made so as to slide out horizontally. Another improvement in the construction enables the whole of the bearing surfaces to run in a bath of lubricant. This type, however, is only used for small engines.

In every type there is a small clearance between the shaft and the inside of the shoe or brass ring, since the block is designed solely to take the thrust of the propeller, and not the weight of the shaft. The block is bolted to the frames of the ship by means of a seating plate on which it rests. This plate is secured by tie beams and girders longitudinally to several frames, so that no excessive strain is exerted on any part of the ship.

With modern thrust blocks the loss due to friction is now comparatively small, although authorities differ on this subject. Good values for the loss expressed as a percentage of the total power are as follows:

	Per cent.
Mercantile marine	0·4
Express steamers and large naval boats	0·5
High-revolution and small naval boats	0·65
High-revolution turbines	1·0 to 1·3

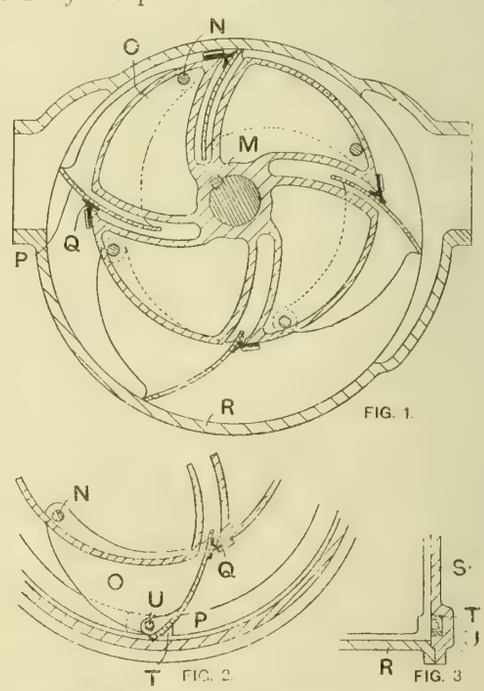
A general rule for all is

$$\text{Loss per cent.} = 0{\cdot}5\sqrt{\text{R.P.M.}}$$

When Parsons' turbines first came into prominence, the thrust block was not so important, as the steam pressure was arranged to balance the thrust; but now that helical gearing has been introduced the thrust must be taken up as before. Experiments have been carried out with roller and ball bearings, but these have had, so far, little success. Perhaps now that greater accuracy in making the balls has been obtained, this may be more successful.

IMPROVEMENTS IN ROTARY BLOWERS.

THE accompanying sectional views show a design of positive rotary blower of the type comprising a spider or drum which is eccentrically mounted in a cylinder and to which are hinged at spaced points blade-carrying arms, the invention of Messrs. J. and G. Keith, 27, Farringdon Avenue, London, E.C. The blower comprises a spider or drum M on which are hinged at spaced points N a number of sets of arms O, each carrying a curved blade P, the axis of curvature of which is substantially collinear with the axis of the corresponding hinges. At spaced points on the external periphery of the spider or drum M are fitted a number of strips Q of felt or other suitable material, with which strips the convexly curved faces of the blades P are in effective contact. The strips Q are formed to function as cup leathers. The blower is adapted to be run in either direction. The edges of the blades contacting with the wall R of the cylinder may, if desired, be fitted with wearing strips for engagement with the internal cylindrical wall R. With a blower constructed as described, the force exerted on the blades P by the pressure of the fluid in front has effect



SECTIONAL VIEWS OF ROTARY BLOWER.

merely on the hinges N and is not transmitted either to the cylinder or to the stationary strips Q. Further, there is no tendency for the fluid pressure to blow the blades P inwards no matter in what direction the blower is run. The blades may be maintained in their outward position by the action of centrifugal force, or springs may be fitted on the hinge pins so as to maintain the blades in outward position by spring action. As shown in Figs. 2 and 3, the cylinder cover S may be grooved for engagement by guide blocks T, each block having a slotted aperture into which projects a pin U on the corresponding blade; the dimensions of the slot being such as to leave the blade free to make proper contact with the internal cylindrical wall by the action of centrifugal force or of springs.

VENTILATION REQUIREMENTS AND TEST METHODS.*

BY DR. E. V. HILL.

VARIOUS experiments have been tried in the past to provide ventilation. The first experiment was with windows, and while they served the purpose admirably when a large air space per occupant was available, it was soon found that in cold or inclement weather, where a large number of persons occupied a limited space, window ventilation was unsatisfactory and insufficient. Various types of ventilators and ventilating flues were experimented with and still have a limited field of application. But little actual progress was made until the invention of the centrifugal fan.

In 1847 Mr. Buckle presented before the Institution of Mechanical Engineers data for the design of a fan which does not differ greatly from those of the present time. From this to the modern multi-blade type is only a short step, and the improvement is probably only in an increase in efficiency of 10 or 15 per cent. With this device, together with a suitable arrangement of distributing ducts, heaters, &c., a continuous and adequate air supply can be secured and controlled at a minimum of expense. This was the solution of the ventilating problem up to within comparatively recent years. Installations were made during this period on the assumption that if 30 cub. ft. of air per occupant were introduced into a schoolroom or assembly hall, and a constant temperature of 69° or 70° maintained, nothing more could be desired, and the room was considered as being thoroughly, effectively, and scientifically ventilated.

It soon became evident, however, that this so-called plenum system of ventilation was not altogether satisfactory. The air conditions, where rooms were ventilated in this manner, gave rise to severe criticism from teachers in schools, physicians in hospitals and similar institutions, even though the best of engineering skill in design and the constant operation of equipment was practised. For example: The teacher in a school would complain (and still does) of poor ventilation. The man in charge of the heating plant would come up and look at the thermostat, see that the required temperature was being maintained and that the proper amount of air was being introduced, and straightway conclude that the teacher had no cause for complaint.

In many hospitals mechanical equipments have been thrown out and window ventilation substituted. This unsatisfactory condition was largely responsible for the appearance of the natural-ventilation faddist or open-window crank, who would rather have his fresh air through an open window than from any patented or mechanical device. We often see statements made by otherwise well-informed individuals that so-called natural ventilation, by means of open windows, is much to be preferred to mechanical. To those who have made a study of this question these statements appear ridiculous. It is perfectly proper to laud natural ventilation by means of open windows, where this method is applicable, and it is also proper to condemn certain methods or individual mechanical installations, but to condemn mechanical ventilation *per se* is an indication that the person so speaking is not well acquainted with the broad requirements of air conditioning.

The natural outdoor temperature must be increased in cold weather by means of artificial heat, and it is in this way that the human race has made regions comfortable which were previously uninhabitable. The question of an air supply has not been given the same study by sanitarians, and catchy phrases like "open the windows," &c., meet a ready acceptance even though it is impractical or even impossible to obtain a clean and pure air supply in this manner. I do not wish to be understood as condemning the free use of open windows where the desired results can be obtained from their use, but I do object to the preaching of natural ventilation where it is entirely impractical. It is an artificial condition where several hundred or thousand people congregate in a room where a temperature of possibly 50° above the outside is maintained, and it is foolish to speak of natural ventilation in a case of this kind. The only method of supplying air of the quality and quantity necessary for the health of the occupants must be by a mechanical system.

On the other hand, it is evident that the criticism of buildings mechanically ventilated in many instances are just, and the demand for the use of windows, especially in school buildings, has a sound basis. The explanation appears to be that many of the important factors in the ventilation problem have been ignored or misunderstood and satisfactory results, therefore, not obtained. This condition has given rise in recent years to considerable investigation in various quarters, and while it is possible that we have not arrived at an ultimate solution of the problem, still enough work has been done and sufficient data collected from which to formulate ventilation requirements which, if enforced, will give satisfactory air conditions in our schoolrooms and assembly halls regardless of weather conditions outside.

I will not take the time to review all the work done by physiologists in recent years in an attempt to solve this problem, but will direct your attention to a few of the important results of their researches. The work of Leonard Hill and his associates brought out: (1) The relatively innocuous nature of carbon dioxide in respired air. (2) The necessity for perceptible air movements in mechanically ventilated spaces. (3) That a high relative humidity, especially in connection with a high temperature, is responsible for much of the depressing effects in poorly ventilated rooms. (4) The Chicago Commission on Ventilation in the experimental room of the Chicago

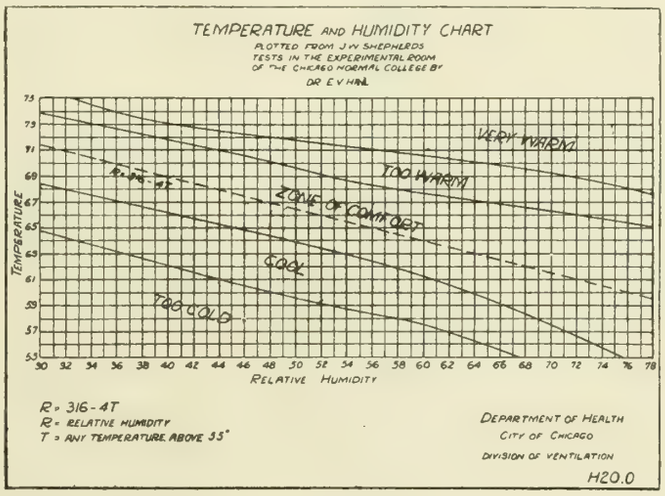


Fig. 1. Comfort Zone Chart, Showing Relation Between Temperature and Relative Humidity.

Normal College, has conducted experiments which bring out the relation between the temperature and humidity in its bearings on comfort. The Comfort Zone Chart was plotted from 152 experiments with varying degrees of temperature and humidity in this room. (See Fig. 1.) (5) Considerable data has been collected by the Division of Ventilation of the Chicago Health Department, showing a rather constant relation between dust and bacteria in the air of theatres, schools, and assembly halls where rooms are ventilated by the use of windows or with a mechanical equipment without an air washer. Probably the most valuable work of the Ventilation Division has been in devising instruments and standardising tests and test methods in ventilation work. The importance of the CO_2 analysis as an indication of the air supply and distribution has been carefully worked out and is now quite universally followed. (See Fig. 2.) (6) Work of the New York Commission on Ventilation, which tends to show that the appetite of persons confined in rooms mechanically ventilated decreases with the air supply. The findings of this commission also bear out the assertion made recently by Prof. Winslow that old standards as to air supply have not been changed by recent investigations, although different reasons are now given for the standards used. (7) Observations from various sources, bringing into prominence the importance of odours as a factor in ventilation work. This research work in various quarters is still in progress. It has already given us a much better basis on which to formulate requirements. It also affords an explanation of many of the poor results noted

* Abstract of paper read before the Western Society of Engineers.

from the operation of mechanical equipments in the past. From the information outlined let us now formulate requirements for good ventilation practice.

Adequate Air Supply. This will of necessity vary for different buildings and types of occupancy between 20 c.f.m. per person as a minimum and 30 c.f.m. as a maximum. It is extremely doubtful if, under ordinary conditions, proper ventilation standards can be maintained with less than this amount. It is also a question whether the expense incurred in providing more than the maximum specified is warranted. These standards are to apply where the air is obtained either by a natural or mechanical system. Where air is re-circulated, washed, and otherwise conditioned, it is possible that the minimum of 20 cub. ft. per person can be somewhat reduced. However, as the expense incurred in additional equipment is considerable, and as it is still an open question whether any reduction, as stated, is compatible with the health of occupants of such rooms, this is a question that must be thoroughly studied and definite data accumulated before more can be said on the subject.

Comfortable Temperature.—This will depend again upon the nature of occupancy, it being from 60° to 65° where the occupants are actively employed, 68° to 70° when they are in repose. The humidity maintained also has a direct bearing on the temperature necessary for comfort.

Proper Humidity. As intimated before, there is a percentage of humidity which is most comfortable for a given temperature. This humidity may be determined within the short range of indoor temperatures from the formula $R = 316 - 4T$, in which T is the temperature of the room and R the corresponding relative humidity. (See Fig. 1.)

Perceptible Air Movement.—It has been shown by various investigators that the removal of the aerial envelope from the body is necessary if normal heat distribution is to be maintained and individual comfort preserved. This is especially true when the percentage of humidity is high. The removal of this envelope is best accomplished by currents of air in the room which are just perceptible to the occupants. This air movement when the temperature is 68° and the relative humidity 40 per cent. should be about 2ft. per second.

Freedom from Draughts.—The mechanical ventilation of a room or even the ventilation by natural methods must be accomplished without the production of uncomfortable draughts. Air movement exceeding 2ft. per second is uncomfortable to some individuals, especially if the draught strikes the occupants from behind, if its temperature is lower than 68°. It is evident that draughts for a short period of time may be pleasant to one individual and objectionable to another, but continuous draughts over a period exceeding a few minutes cannot be maintained without serious consequences.

Freedom from Dust and other Impurities.—One of the essential requirements in ventilation work, and one which has not been given the attention it should in the past, is the purity of the air supply. Air purity in the past has meant, especially to the layman, freedom from the products of respiratory contamination. Impurities from this source probably are less important than most people think. On the other hand, dust contamination almost of any kind or source is a much more serious difficulty than is usually supposed. The conception is altogether too prevalent that all outdoor air is fresh and pure. This is far from true. The seriousness of the dust nuisance in cities has only recently been appreciated. The dust content of air samples even in clear weather, taken in Chicago, compared with those from rural districts or over Lake Michigan, revealed the fact that there is no time except directly after a heavy rain when the air is anything like what nature intended in purity. Daily counts were made of dust particles in the air from samples taken on the roof of the City Hall for 60 consecutive days during the autumn of 1914. While the counts within 12 hours after a heavy rain were fairly low, averaging from 15,000 to 20,000 particles per c.c., the average condition at other times was very unsatisfactory even at this height above the street. The counts increased in numbers from 15,000 after a rain to over 1,000,000 particles per c.c. during dry weather.

The Maximum Number of Bacteria.—Under ordinary conditions a high dust count means a high bacterial count, and while the greater portion of these bacteria are of the so-called non-pathogenic variety it is becoming more and more evident that the inhalation of the non-pathogenic bacteria is not compatible with the best air conditions from the standpoint of health.

Freedom from Odours.—The importance of this factor can best be brought out by several illustrations. One instance that came to my attention was where a teacher in a school complained bitterly of the foul air in a certain classroom. Upon investigation the following conditions were found: The air supply per pupil was 32 c.f.m., dust count 15, colonies on a 5-minute plate averaged 7, CO_2 7 parts. In spite of the apparently satisfactory conditions shown from the foregoing tests, there was an unmistakably bad primary sense impression. A careful examination was made of the region about the intake and the ducts in this room, without being able to locate anything that would throw light on the question. The information was finally gained from one of the pupils that a girl sitting in the seat opposite had lost her pet canary by death. She had laid out the remains in a thread box and kept the same in her desk until it was discovered. The odour was so slight that it was almost impossible to recognise it as an olfactory impression, nevertheless it was sufficient to cause a definitely bad air impression in the room. Many instances of a similar nature might be recounted.

You will see from the foregoing that the problem of ventilating an enclosed occupied space contains many variable factors. Simply supplying a certain amount of air and main-

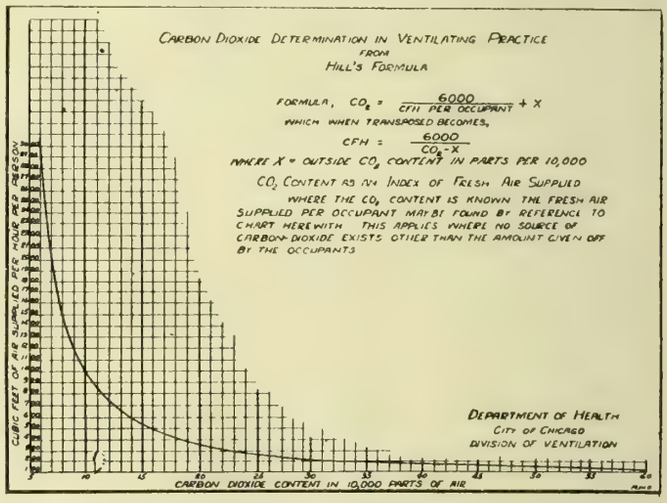


Fig. 2. CO_2 Chart, Showing C. F. H. to Maintain Any CO_2 Content.

taining a certain temperature is not sufficient. We must have in mind all of the various factors previously discussed when testing an equipment and most of them when designing the same.

I will now call your attention briefly to some of the important features in correct design, and then describe the methods used in testing the completed installation. There are at least 10 features in mechanical design that should be considered by the engineer when laying out his work. They are: (1) Proper location of the fresh-air intake; (2) temperature control; (3) elimination of dust and other impurities; (4) humidification and de-humidification; (5) air distribution; (6) accessibility of all parts of the equipment for cleaning; (7) pressure requirements; (8) accurate duct design; (9) relation of design to installation; (10) relation of design to economical operation.

The Proper Location of Intake.—It has been repeatedly demonstrated that where an intake is located in a sidewalk, bulkhead, window, or other low point close to traffic, or even at points as high as 10ft. above grade, contamination of the air supply with dust and dirt is very large even though an air washer is used, for it is a well-known fact that the efficiency of air washers in dust removal varies from the maximum of 95 or 96 per cent. under favourable conditions to as low as 10 or 15 per cent. under unfavourable conditions.

Temperature Control.—Heat control, preferably by thermostatic means, is almost imperative in auditoriums or classrooms. This is not because the temperature in the room must

of necessity be maintained at a fixed point, but to prevent subjecting the occupants to cold draughts of air. A floor introduction plant may be perfectly satisfactory when the air is being brought in at 68°, but would be extremely unfavourable supplying the same amount of air if the temperature falls to 64° or 65°. This illustrates the necessity of accurate temperature control where the occupants of a room must of necessity be close to the supply registers.

Elimination of Dust and other Impurities.—The fact that dust is something more than a mere inconvenience, as was formerly supposed; the fact also that it gives rise to objectionable odours or deleterious substances when decomposed by the heaters, makes it plain that air washers or other means of dust removal must come into universal use in city work.

Humidification and De-humidification.—We have spoken of the desirability of a proper amount of moisture in the air only from the standpoint of comfort. While this is important, it is more important from the standpoint of health that we realise fully the bad effects of the low humidities maintained in cold weather, and also of the depressing effects in high humidities in moderate weather. It is perfectly apparent that every school building should be supplied with an efficient air washer and humidifier and devices for automatic humidity control in cold weather.

Distribution.—Much has been said in recent years regarding the distribution of air, but little has actually been done. Much discussion has prevailed regarding the comparative value of upward as against downward ventilation. I feel strongly that there is no room for an argument of this kind; in fact, there is no room for arguments regarding methods of air distribution at all. Every problem should receive individual attention regarding the means and methods employed, taking into consideration exposed walls and windows, the temperature of the entering air, the configuration of the room or building and the various other factors that bear directly on the problem.

Cleanliness of Air Ducts and Equipment.—This phase of ventilation work is one that has never been given even passing notice, so far as I am aware. We find that in practically every ventilating job installed no consideration has been given to the cleaning of the ducts, and in some instances to coils, fans, &c., after the original installation. I can point to several schools in Chicago where an accumulation of carbon, grease, and other impurities in the fresh-air ducts is so extensive that they look and smell like the inside of an old chimney. In one installation, where complaints from the teachers were persistent, this was the only difficulty, and a thorough cleaning with an alkaline solution and a hose remedied the objectionable odours which were not even recognised as such but which were the sole cause of the poor results obtained. There should be no part of the fresh-air supply of a mechanical equipment that is not accessible for thorough cleaning at least once a year.

Pressure Requirements.—Considerable discussion and some ill-feeling has resulted from the rule which is more or less universally followed in school buildings throughout the country. I refer to the requirement that windows be kept closed in school buildings during occupancy, on the assumption that opening them unbalances the ventilating equipment. While this is true in many cases, it is a situation that should not obtain and one for which there is no excuse. Without entering into a discussion at this time of the merits or demerits of opening windows in classrooms, it must be conceded there is serious objection to a rule forbidding the practice. The psychic effect is bad if one is forbidden to open a window and conversely there is a certain value from the same standpoint if further use of windows is allowed when weather conditions permit. There is no excuse for the design or installation of a mechanical equipment in a school building that does not allow of the full use of windows. It is only necessary to carry a low velocity and a high static pressure in the mains, throttling either at the throat of the branches or at the outlet registers, so that the difference in pressure beween the main and the room is considerable, to nullify the effect of opening any of the windows in a building. This is a matter that should be brought to the attention of designing engineers in school work.

Accurate Duct Design.—Another practice which is prevalent, but which should be discontinued, is the haphazard method of designing ducts to carry certain air volumes, irrespective of the static resistance in the same. It is much easier to guess at the size of the ducts required and to control the air volume by means of splits and dampers than to design each branch with the view of making the static resistance control its air supply; however, the air split method is extremely unsatisfactory. Proper adjustment is extremely difficult, and when one damper gets out of adjustment the whole system is disarranged. If the equipment is properly designed without air splits or dampers, it cannot become disarranged or out of adjustment, and much better results will follow.

Careful Installation.—It is not a difficult matter for the engineer to properly design the entire equipment, even to the minutest detail, but it is too often the case that the superintendency of installations is left to some person who does not realise the difference made in an improper turn or a poorly constructed duct. This is one of the principal reasons why air splits and dampers are so often resorted to. It is apparent, however, that if heating and ventilating engineers would meet and overcome the objections and complaints arising from improper operation of mechanical equipments they must see to it that the installation is made in accordance with the design.

Economical Operation.—This is important in all cases, especially so in small plants where the necessity for mechanical ventilation is not fully appreciated.

A phase of ventilation work that has been neglected to a certain extent in the past is the testing of the completed equipment to see that the desired ends have been obtained. It also has to do with the testing of air conditions where the supply comes from the open window or any other source. This side of the ventilation problem is of extreme importance. I will divide methods of testing into five subheads, as follows:—

(*a*) *Air Velocities.*—(1) Anemometer, (2) Pitot tube and gauge.

(*b*) *Air Movement.*—(1) Ammonium-chloride test, (2) phenol-phthalen test, (3) balloon test.

(*c*) *Air Analyses.*—(1) Taking samples, (2) analysing samples.

(*d*) *Bacteria.*—(1) Culture methods.

(*e*) *Dust.*—(1) Aitken portable dust counter.

By means of these test methods we determine to what extent the requirements for proper air conditions previously discussed are accomplished in installations being tested.

Anemometer.—The anemometer consists of a small wheel carrying eight vanes. The wheel is connected by suitable gearing to indicating hands on the dial and the instrument is so calibrated that the revolutions of the vanes indicate the velocity of air passing through the instrument in feet per unit of time. The wide divergence in the readings obtained by two persons with the same anemometer, under the same conditions, should not be attributed to inaccuracy of the instrument, but rather to ignorance or carelessness in its use. The first requisite is that the instrument be in good repair and properly calibrated. The second is that the readings be accurately timed. The third is that the proper method of taking readings be employed.

In taking readings at the register face the method of slowly moving the anemometer across the register or up and down, as the case may be, is only mentioned to be condemned. The reading will be inaccurate except at those registers where the velocity is uniform throughout the entire area. In taking readings where the velocity varies over different areas of the register face, it can readily be seen that in moving the instrument slowly across the face of the register the momentum acquired by the revolving vane over the areas of high velocity will cause it to continue to revolve at a much higher rate than it should while passing over the areas of low velocity, consequently a much higher average velocity reading will be obtained than the conditions warrant. The proper method is to divide the face of the register into equal areas of approximately 6in., and take one-half or one-minute readings at the centre of each square. The average of the total number of readings times the area of the opening will give the cubic feet of air delivered.

Pitot Tube and Gauge.—The velocity of air flowing through a given duct depends on the difference in pressure maintained

between the entrance and outlet. It is necessary to consider this pressure as made up of two components: (1) that which is required to compensate or overcome the loss due to compression and frictional resistance (static pressure); (2) that which is necessary to move the volume of air at the given velocity (velocity pressure). The sum of the two is the total or dynamic pressure. The air velocity is determined from the formula $v = \sqrt{2gh}$, which transferred into terms of air becomes $v = 1096{\cdot}5\sqrt{\frac{P}{W}}$ where v is the velocity in feet per minute, P is the velocity pressure in inches of water, and W is the weight of one cubic foot of air at the given temperature. As there is no way of determining the velocity pressure directly, the total and static pressures must be determined and the latter subtracted from the former to obtain the velocity pressure. For making these determinations the Pitot tube is the most satisfactory instrument from the standpoint of accuracy and convenience.

Ammonium-chloride Test.—When strong ammonium hydroxide and hydrochloric acid are volatilised and the two gases brought into contact a chemical reaction results with the production of ammonium chloride. This ammonium chloride occurs in a very finely subdivided state, is distinctly visible as a white cloud, and does not readily settle out of the air. This is a valuable method for studying the direction and velocity of the air currents in a room. The apparatus consists of two 25 c.c. bottles carried in a small leather case, one containing the acid and the other the ammonium hydroxide. By means of a small rubber force pump air is bubbled through the two bottles and the volatilised products brought together at the nozzles of the tubes projecting from each. In this way the cloud of ammonium chloride is produced conveniently in any location and its action observed. For determining the velocity of the air movements in a room a puff of the smoke is produced and its direction noted. The second observer then stations himself 10ft. away, in the line of the air motion, from the one holding the apparatus. A puff of the smoke is now liberated and by means of a stop watch the second observer notes the time the cloud reaches his station.

Phenol-phthalen Test.—This test depends upon the reaction which occurs in a weak alcoholic solution of phenol phthalen when acted upon by a strong alkaline reagent.

Balloon Test.—Small toy balloons are inflated with hydrogen gas and counter-poised with small improvised weights. These weights are just sufficient to keep the balloons in the air at the temperature of the room. They are liberated at various points and give a very interesting visual demonstration of air currents.

Air Samples.—The apparatus for taking air samples, to determine the carbon dioxide content, consists of clean rubber stoppered bottles holding about 120 c.c. each, a Paquelin cautery bulb and 24in. of tubing. The apparatus is held at arm's length from the body, great care being exercised that the expired air from the observer's mouth does not contaminate the sample. The cork is removed and the tube inserted to the bottom of the bottle. The tube is closed by pressing it between the thumb and the neck of the bottle and the bulb is compressed until the reservoir is distended. The thumb pressure is then released and the air in the reservoir allowed to rush into the bottles, displacing the residual air. This operation is repeated three times in order to be sure that all of the air originally in the bottle and apparatus has been replaced by the air to be sampled.

Analyses of Samples. Analyses are made for carbon dioxide with a modified Peterson Palmquist apparatus. Regarding the analysis for carbon dioxide in ventilation work, I would like to call your attention to the following: The prevalent opinion in the past, especially among the laity, has been that carbon dioxide, being the product of respiration, is necessarily injurious; in fact, it has been considered by some as the most injurious substance in vitiated air. This theory was discarded 60 years ago and Pettenkoffer called the attention of the medical profession to the fact that its use was only valuable as an indication of other respiratory impurities. We use it at the present time only as an indication of the amount of fresh air supply and for no other purpose. Knowing the average amount of carbon dioxide exhaled by the audience, and knowing also, or determining by test the amount in the outside air, it is a simple mathematical calculation to determine from the average CO_2 analysis in a room the fresh air being supplied. This is valuable to check on, supply and distribution, where a mechanical equipment is being tested, and it is extremely valuable in determining the amount of air supply in an auditorium, room, or other occupied space where the air supply is obtained solely through natural means. The formula and chart used for this purpose is shown in Fig. 2.

Bacteria Culture Method.—Cultures for the determination of bacteria are made by exposing Agar plates for a period of three minutes. These culture plates are then placed in an incubator for 48 hours at room temperature and the colonies that develop are counted.

Dust.—The determination of dust in the air is a matter that is being given more attention than ever before. We have experimented with various methods, and while none of them is entirely satisfactory, the Aitken portable dust machine has given us the best and most consistent results up to the present time. The machine consists of a chamber lined with hygroscopic material; a filter for obtaining clean air; a measuring device and a rule objective for counting the dust particles obtained. The principle on which this apparatus works is as follows: The air from the room is drawn through the filter into the chamber until the latter is filled with air free from dust. A slight vacuum is now produced in the chamber by means of the pump and then a measured quantity of the dusty air to be sampled introduced. This is mixed in the chamber thoroughly and a further reduction in the pressure caused. This lowers the dew point and causes each dust particle to act as a nucleus for the condensation of moisture which falls in a fine shower of rain on the observation plate at the base of the chamber, when it may be counted by means of the magnifying eye piece. A modification of this method, suggested by Mr. Hoskins, has been adopted with exceedingly gratifying results. It consists of a smoked disc of glass or cover slip, as it is called, being introduced into the chamber and the dust particles precipitated on the inside on the observation plate just referred to. These cover slips may then be removed and counted at leisure. In this way a permanent record of tests may be kept.

IMPURITIES IN SPELTER.

IN a paper recently presented before the National Hardware Association at Pittsburg, Mr. W. A. Cook discussed the effect of impurities on zinc, and especially the effect of cadmium on brass, as follows:—

Spelter, with few exceptions, contains lead and iron, these being the chief impurities. Cadmium is frequently present in small amounts. In still smaller quantities, usually little more than traces, arsenic, antimony, sulphur, and copper are also found. Tin may also occur in remelted spelter. In some special brands of high-grade spelter the lead does not exceed 0·02 per cent. and iron 0·01 to 0·02 per cent. In good ordinary brands from 0·4 to 1·0 per cent. of lead and 0·03 to 0·05 per cent. of iron are usually found.

Effect of Impurities on Spelter.—The effects of impurities on the metal are as follows:—

In spelter intended for rolling a small percentage of lead is desirable, and up to 1 per cent. it has no injurious effects on the malleability or ductility of the metal. When the spelter has to be used for making brass which has to undergo severe mechanical treatment, as, for example, the manufacture of cartridge cases, it should contain as little as possible, not exceeding 0·1 per cent.

The effects of iron are to increase the hardness and brittleness of zinc and reduce its malleability, but when the refining by liquation has been properly conducted there is insufficient present to affect these properties. When iron is present in excessive amounts the bright cleavage planes of the fresh fracture of a cake will show grey specks scattered over them. For spelter intended for the manufacture of brass, 0·05 per cent. of iron is often specified as the limit, but it is best lower for brass of high ductility and malleability. Zinc may be completely freed from iron by re-distillation, the use of iron tools and appliances being avoided.

Cadmium is a material closely allied to zinc with the ores of which it frequently occurs. It is tin white in colour, malleable and ductile, and brilliant in lustre when fresh, but becomes dull on exposure to the air. Its malleability and ductility are such that it can be beaten out into thin foil and drawn into wire. Cadmium is rarely present in zinc in injurious proportions. It is especially liable to occur, however, as Prof. Ingalls claims, in re-distilled zinc. In two plates of a sample half ton of so-called pure re-distilled spelter 5·08 per

cent. of cadmium was found, but this is very exceptional. Muntz metal made with this spelter broke with a crystalline fracture closely resembling that produced by antimony. However, no sensible effect on the properties of zinc is produced, even when 1 per cent. is present, and nearly always the percentage does not reach that amount. It is said to discolour "zinc white" made from zinciferous materials containing it.

Tin tends to make zinc very hard and brittle in rolling, and although it is not of common occurrence, except in re-melted spelter, as Prof. Ingalls states, yet it should always be looked for.

Arsenic, antimony, copper, sulphur, and carbon are scarcely ever present in sufficient quantities in spelter to affect its properties either for rolling or the manufacture of alloys. Arsenic, however, should be absent in zinc intended for the precipitation of gold in the cyanide process.

Effect of Cadmium in Zinc or Brass.—I would like to call your attention to a paper that was prepared and handed to me by one of the best-known metallurgists in the United States, in connection with the question of cadmium in brass mixtures. He has made extensive tests on this subject and it is fair to assume that his conclusions are right. While this question has not been made the subject of very exhaustive researches by manufacturers of copper alloys and very little appears in scientific publications relating to it, at the same time it has been the cause of considerable discussion among metal users. The results of what might, at the present time, be called incomplete investigations, indicate that cadmium when present in spelter in amounts as high as 1 per cent. and over would be detrimental to the manufacture of high-class brasses such as are used for cartridge metal or deep drawn stock.

In quantities less than one-half of 1 per cent., however, personal experience has proved that cadmium need not be considered as having injurious effects on brass mixtures. As a matter of fact the difference in volatilisation points of cadmium and zinc plays a most important part in the reaction which takes place when the metals are heated. Zinc melts at 415° C. and boils at 940° C., so its volatilisation point may be taken at somewhere near its boiling point. Cadmium melts at 320° C. and boils at 778·6° C. Therefore, it will be seen that there is sufficient difference between the two so-called volatilisation points so as to enable a separation to be made of the two metals by heat, and as a matter of fact this is what is done in the production of cadmium itself.

This difference also in temperature, of course, leads to the logical conclusion that cadmium will oxidise at a lower temperature than zinc, and this is a fact. So it might be said, with entire accuracy that, in using a spelter containing an amount of cadmium up to one-half of 1 per cent., the cadmium will act as a deoxidiser on the copper and form CdO or cadmium oxide and come to the top of the pot of metal before the zinc performs the same office, and it is the writer's personal experience, upon the analysis of such metal made with zinc carrying cadmium, no cadmium was found in the brass so made.

Of course, cadmium that might remain in the brass and exist as a cadmium-copper alloy or cadmium-zinc-copper alloy would cause the resulting brass to be brittle and would not admit of the malleable properties that are required in commercial brass. Now in the case of brass, we first melt copper at a temperature of approximately 1,100° C. and then into this we introduce the zinc which melts at 415° C., and consequently there is every chance for the cadmium to volatilise and oxidise and therefore our cadmium, as said before, is removed in this way.

As a summary then of what is said above, it is the writer's experience that cadmium in zinc in amounts anywhere up to one-half of 1 per cent. is not at all prejudicial for the use of such zinc in the manufacture of brass. Cadmium is used in electroplating in connection with silver, properly proportioned, making a whiter, harder, and more durable finish than pure silver. To show its impervious nature two steel tubes were prepared, one nickel plated, and one cadmium plated, and they were exposed to conditions of rapid rusting. In due time the samples were taken out and the steel nickel plated tubes were completely covered with rust, and the tubes prepared and plated with cadmium were perfectly good and showed the impervious nature of the cadmium. Cadmium with a small percentage of silver has been employed for a number of years in England for coating steel parts with success.

GOOD AND BAD LUBRICANTS.*

BY G. BASIL BARHAM, A.M.I.E.E.

WHATEVER an economist might advise or do, no engineer would select a lubricant on account of its lasting qualities alone. To him they would be quite a secondary consideration; he would require to be assured that it would keep cool the moving parts on which it was to be used before he would go into the question of whether it would or would not last longer than some other lubricant he was using or had under consideration. The first essential of a lubricant, from an engineering point of view, is that it should possess a low and constant coefficient of friction. If the friction is small the heat generated will be small. Providing the lubricant used will float the parts and allow a film to be maintained, it only remains that the characteristics which tend to set up friction by resisting the relative movement of the parts, should be as few and as inappreciable as possible.

It is not easy, however, with all lubricants to maintain this film; with some it is not an easy matter to ensure an adequate supply passing to the point where it is required. Some lubricants will squeeze away and leave parts starved; others, of the composite variety may give up one or more of their constituents and leave the "filling" to clog and bind, and ultimately cut the surface of the parts. Further, if it were only a matter of a low coefficient of friction, practically any clean oil, whether animal, vegetable, or mineral, would answer the purpose, provided it was fresh and in good condition. But any attempt to lubricate machinery for any length of time with either animal or vegetable oils would have disastrous results, as all organic oils undergo chemical changes, and either turn rancid, or thicken and gum. The only oil that can be used for lubricating purposes with any good and sustained result is a mineral oil, and unless this has been chosen, and treated specially by processes dependent upon expert knowledge not only of oils, but also of the purposes for which each is intended, the results are not likely to be satisfactory. It is emphatically not a case of "any old oil will do," where high-speed electrical and other machinery is in question; it is a question of comparative expense and expediency. Engines and generators cost more than lubricants, and it must be pointed out that oil, no matter how excellently it be blended, has its limitations, and there is a question as to whether, in view of modern developments, it is not bad engineering to use oil at all for lubricating purposes.

It is a fact that while types of prime movers have been standardised, and dimensions and proportions resulting from wide experience have been adopted for prime movers, one feature of design, *i.e.*, engine lubrication, has not kept pace with other developments. It is not too much to say that quite 80 per cent. of engine troubles are due to defective or improper lubrication. The other 20 per cent. can be about equally divided between careless or ignorant operation and inadequate proportions of working parts. Chemical grease extractors have been introduced, some of which have been more or less successful, but as a general thing the difficulty has been so great that many power users have adopted the use of solid lubricants, and hold the opinion, to which many are being converted, that in some form these will be the lubricants of the future. It is claimed that they increase the efficiency of oiling and minimise waste, and there is no doubt that, if of high grade, soap-solidified oils and greases can be successfully used on a number of parts which have to stand heavy duty. At the same time objections can be advanced against both these lubricants themselves and the methods in which they are generally used.

In the majority of cases solid or semi-solid lubricants are made by working up animal fats or vegetable butters with soap and water, or by thickening mineral oils of thin body but extreme viscosity with soap. The soaps used are of the ordinary lime, soda, or lead types, and it must be pointed out that it is not an easy matter to prevent an excess of caustic soda being present. During use this is being converted into carbonate of soda, and there is a danger of the bearings being cut in consequence. Such greases frequently contain free fatty acids which attack the metal parts on which they are used. Further, when thickened mineral oils are used, there is a liability for the oil content to be squeezed away,

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leaving the soap body behind it in the bearing, where it not only hardens but forms a nucleus to which any abraded metal particles and dirt adhere. In this way a gummy mass is formed which soon coats the moving parts, increasing friction and leading to ultimate cutting. Where such lubricants are used in boxes it is common practice to fit these with brass pins which rest in the part in motion. Should friction increase beyond the normal, and heating be set up, the theory is that these pins become heated also and cause the grease round them to flow to the journal. Should a bearing lubricated in this way run very hot through neglect, and escape notice, in a very short time the whole of the grease will have run through, and thus allow the brass pins to work down between the shaft and the brass or the cap of the bearing and so grind up, cutting both shaft and bearing.

The same objections cannot, however, be urged against high-grade non-fluid oils. They have all the advantages of soap lubricants but none of their disadvantages, and in addition they possess the property of adhering to metal surfaces with a force which is considerably above that possible with fluid oils. They are all of high viscosity and can only be fed drop by drop. In that they prove economical, as with ordinary oil a greaser can and frequently does squirt oil with a lavish liberality not only on the part needing it, but also on any parts adjacent. It is not to be supposed that this slow feeding is a disadvantage even where a bearing has run hot, as, owing to its clinging properties, it films immediately on reaching the moving part and so forms an ideal lubricant. Non-fluid oils, also, will not gum, and they can be used without risk of clogging in central distribution systems provided the oil tubes are of sufficiently large internal diameter to permit of the oil flowing.

In practice it has been found that one pound of non-fluid oil of high quality is equal in lubricating effect to one gallon of high-grade fluid oil, and according to the average prices ruling the saving effected in direct cost by using such lubricants would be about 65 per cent. or more, according to the quality used. The extremely low average coefficient of friction possessed by high-grade non-fluid oils has been proved by numbers of independent tests, and such oils are being largely used with high-speed machinery, being mechanically fed to the various parts. But where the adoption of non-fluid oils is contemplated, it must always be remembered that a lubricant which would suit a certain class of machinery might be of little use for another. As has been said, the art of economically employing a lubricant consists mainly in the application of precisely that quality which is best adapted to that particular place on each machine or each part of a machine on which pressure of lubricated surfaces of widely differing amount is found, and, above all, applying it in the best possible way.

Of recent years the claims of graphite to be considered the ideal lubricant have been supported by a large and increasing number of engineers. It is common knowledge that when used for such purpose graphite should be of such quality and fineness as to give a perfectly smooth and even veneer or coating to the parts. The danger is that an impure or carelessly prepared grade might be used, which would carry into the bearings or cylinders such impurities as are naturally associated with graphite, as sand, clay, mica, or talc. The essentials of good lubricating graphite are that it should be amorphous and of extreme softness. It should have neither lustre nor brilliancy, and a heaped quantity of it should not reflect light, nor show bright particles when examined with a powerful lamp. The colour is not so important; dense blackness does not necessarily show purity any more than a feeling of smoothness when rubbing a sample between the thumb and finger proves fineness. For example, it may be mentioned that by a special electrical process graphite can be made of such a degree of subdivision that the particles cannot be seen under an ordinary microscope. Ordinary graphite contains particles of about $\frac{1}{350}$in. diam., but electrically-prepared graphite has no particles estimated to be larger than $\frac{1}{120,000}$in. diam. It is, of course, this finely divided graphite which is most generally used for lubricating purposes, and from the results of which the value of graphite as a lubricant will be judged.

On examination under a high powered microscope any metal, no matter how carefully ground, polished, or burnished, will be found to show many small irregularities, which are the real cause of friction. It is the scraping of these, one over another, and the constant cutting or wearing, which is so productive of hot boxes, cut valves and cylinders. The thin, tough particles of graphite attach themselves to, and build up these irregularities, filling up the hollows and forming a thin but practically indestructible veneer-like coating of extreme smoothness. Under no circumstances short of the introduction of some foreign body which would cause scoring before the graphite began its equalising work could the metal surfaces come into actual contact with each other. The film being indestructible, no sudden hammer effect, such as takes place when the load is suddenly switched off a large generator and the armature shaft drops from its floating position, can do damage which might be done were oil used as a lubricant. Oil can easily be hammered out, but there is no known means whereby graphite can be knocked out of position in a bearing. It is noteworthy that flake graphite may be introduced to cylinders, may pass into feed water, may even be purposely placed in the boilers without it doing the slightest injury. For ordinary purposes graphite may be mixed with non-fluid oils, or even with soap-base greases with advantage, but obviously for valve and cylinder lubrication of condenser engines graphite of the purest possible quality should be used by itself or else the old trouble of separating the oil from the feed water would recur.

Graphite may be applied in the following manner: Whenever valves or cylinders are overhauled, graphite mixed with vaseline may be applied to the surfaces, as this will ensure a general distribution. Graphite can be introduced on starting up, through an oil cup or indicator pipe. It can be put in in a dry state, but a better plan is to float it in water and apply it in exactly the same way as lubricating oil is applied. If at any time there should be slight squeaking, or a bearing should start to warm up, a little graphite and water will effect an instant cure.

BULGING OF FRONT FLUE SHEETS OF LOCOMOTIVE BOILERS.

A COMMITTEE of the Master Boiler Makers' Association, reporting at its recent annual convention, gave an account of a test conducted for the purpose of determining the cause and nature of the bulging of front flue sheets in locomotive boilers. By using hand rollers in setting 2in. flues in a ½in. sheet, each hole was stretched ·007 of an inch. With the self-feeding roller and hand pin the holes stretched ·029 of an inch. With the self-feeding roller and air motor the holes stretched ·021 of an inch. On the basis of a flue head having 400 holes in it, the hand rolls would stretch the holes 400 times ·007, which equals 2·8in. The second operation, that is, self-feeding rolls and hand pin, would stretch the holes ·029 of an inch, or 400 times, which equals 11·6in. The third operation of self-feeding rolls and air motor would stretch 400 holes a total of 8·4in. The amount of excess material is distributed over the space worked upon in each case. As the bridges between the flues do not upset proportionately to the increase in the sizes of the holes to do the stretching of the material at certain points, each individual hole must take care of a portion of the material round it, thus making the bulging of the sheet a local condition. From the above, the committee regarded it as plain that the amount of work and the tools used, as well as the experience of the man putting in the flue, governs the bulging of the sheet.

The Value of a Name.—To the average buyer the value of a name is not always, or at first sight, apparent. The naming of a general engineering product, such as a taper pin, might even be considered as something of a superfluity, and yet when Messrs. Frederick Mountford, Ltd., decided to specialise in that direction, and to call the result of their efforts the "Fremo" taper pin, they undoubtedly placed their product on a higher plane. By giving their taper pin a name, and turning out taper pins as nearly perfect as human skill and the finest facilities can ensure, they threw down a challenge to every maker of taper pins, the result being that the demand for "Fremo" taper pins is already greater, and growing at a greater pace than could have been the case with any unnamed taper pin. The name not only enables the user to identify the product which gives entire and consistent satisfaction, but also supplies a guarantee of efficiency which, if not lived up to, can only end in the wrecking of a reputation.

DISTRIBUTION OF THE RAW MATERIALS IN THE BLASTFURNACE.*

BY GEORGE W. VREELAND.

THE proper distribution of the raw materials in the blastfurnace has been the subject of more thought and study than any other factor of furnace operation. This is indicated by the large amount of literature on the subject and the number of methods patented, all striving for what is looked upon as perfect distribution. That the time and thought given to this subject have been productive of good results is absolutely beyond question, but the necessity of a still more efficient distribution continues to occupy the minds of blastfurnace managers and engineers, and, no doubt, will continue to do so until the perfect or ideal condition is attained, or that point is reached beyond which it will be impracticable to go.

The deterioration and bad practice of furnaces can be justly attributed to faulty distribution more than to any other single cause. We have numerous instances where faulty distribution has injured the physical condition of the furnace to such an extent that it has been necessary to blow out the furnace after a very short and troublesome campaign. Many patents have been taken out; innumerable designs have been made; many working models have been constructed and distribution with miniature charges observed which promised good results, but many a hope has been shattered when a supposedly perfect top failed under actual operating conditions. The longer and more efficient life of the present-day furnace furnishes proof of the fact that the efforts to secure a better distribution have been rewarded. On our large furnaces, with their big tonnages, the errors of faulty distribution are more evident than on the smaller furnaces, due to the more rapid rate of driving; but that these errors exist on the small hand-filled furnaces, even with the most approved methods of charging, cannot be denied. Up to the present time, however, no change in the distributing equipment has produced such uniformly good results as to lead to its general adoption, nor has any one top shown conspicuous superiority over all others.

The variety of furnace tops now in use (some stationary, and others rotating in divers ways), the stationary and movable deflecting rings, the numerous ways of placing the raw material (ore, coke, and stone) on the bells and in the furnace, all have their advocates, with data to substantiate their claims. The equations of the blastfurnace have so many variables and so few constants that almost anyone can solve the equation for the particular variable for which he is looking, and apparently prove it to be correct.

The changes and improvements that have been made to effect the better distribution of raw materials in the furnace can be more fully understood and appreciated by giving a brief description in their chronological order of the various methods used.

During the middle ages, when the shaft furnace first appears as a matter of record, the ore, fuel, and flux were, no doubt, simply dumped into the top of the furnace, air was blown into the bottom, and iron produced. Fuel cost and the many economic questions that the present-day manager has constantly before him were not considered.

The first method of filling a furnace of which we have any record is described in an excerpt from a publication of the year 1686. It consists simply of "the throwing in of a basket of ore and a basket of charcoal." In the "History of the Iron and Steel Industry of Great Britain," Abraham Darby is given the credit of being the first man to operate a blastfurnace successfully, using coke as a fuel, and he states that he watched the filling of the furnace for six days and six nights, having no regular sleep and taking his meals at the furnace top. This was about 1735, and from his close attention to the filling it might be inferred that the methods of distribution fell into disrepute at an early date.

It appears that during the early years the top or mouth of the furnace was of very small diameter, as we read that the Blendare furnace, Pontypool, Wales, had an accident which caused the inner portion of the lining near the top to give way, thereby increasing the diameter of the top from 3ft. to 9ft. Operation was continued, however, and the accidental increase of the diameter to 9ft. resulted in much cooler top gases and better furnace practice. This must have been considered a marked improvement, as when the furnace was rebuilt the diameter of the mouth was increased to 10ft. This led to a similar change on all furnaces operating at that time. It may be inferred that this marked the beginning of circumferential charging. From copies of old prints we find that even previous to the "cup and cone" arrangement, furnaces were equipped with a tunnel head, consisting of a stone or brick structure encircling the mouth of the furnace. This, in my opinion, was primarily intended to act as a conductor of the gases, but it must also have served as an aid to the better distribution of the raw material, as we find that this structure was provided with openings of sufficient height and width through which the raw materials were dumped. I understand that a few years ago several furnaces in the Cleveland district, of the customary bell-and-hopper type, were equipped with these tunnel heads, but of steel-plate construction; and the gas was taken through off-takes at the periphery. After the introduction of the hot blast, quite a number of devices were tried to take the gas off centrally; and provisions were also made for the better distribution of the materials.

The bell-and-hopper arrangement was introduced into Wales in 1850. In his book, "Iron and Steel," Dr. Percy states that when the closed top was first introduced an inferior grade of iron was made in some instances; and he informs us of an experiment which was made in which it was found that upon the installation of the "cup and cone" on a furnace that had previously produced grey iron, nothing but white iron could be produced even with increased fuel. This created some prejudice against the further use of the closed-top type of furnace. Soon after the general adoption of the closed-top furnace, a great number of patents were granted on methods for the distribution of materials. The greater number of these, however, were used at a time when the chemical and physical properties of the raw materials were entirely different from those we find to-day. Several of these methods had a central gas off-take and were intended to distribute the finer portions of the materials in the centre of the furnace to prevent the direct pull of the gas, which might have happened had the coarser materials been dumped in the centre of the furnace. In order to get satisfactory penetration and to produce the quality of iron desired at that time, which, of course, was much different from the quality desired to-day, the diameter of the hearth was very small. These various methods were all designed with the view of distributing the materials to the best advantage under conditions as they were at that time. Foremost among them were the Baumann bell and hopper, the Durham, the Baumann-Firestone, and the Witherbee double bell. These various methods have been so well described that I will not go into detail here, especially since they are not in use at this time. The main points of difference were the number of concentric rings of material formed in the furnace. I understand that excellent results were attained with some of these devices, and that some of them, or modified designs, are still in use on the lumpy ores in Germany. But on our fine ores of the present day they are impracticable.

The single bell and hopper with hand filling remained in general use, with no great change in its general design and no attempt made to charge the furnace by mechanical means, until all other parts of the furnace had been developed to such an extent that it was physically impossible to keep the furnace full. With the advent of the fine ores and the attendant dangers to top fillers, due to slipping, many efforts were made to substitute some mechanical means of charging the furnace, but these methods were so crude that they were temporarily abandoned. In some cases the skips were removed, the time-honoured method of hand filling, which system allowed greater flexibility in the arrangement of the materials on the bell, prevailing. There are several mechanically-filled furnaces, however, which survived this period, one of which is now in operation at Steubenville, O. This furnace is equipped with the Fayette Brown skip hoist, built in 1885, with an orange-peel opening for the receiving hopper, which is square. The

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No. 1 Lucy furnace, whose skip was built in 1884-5, is also in operation at the present time.

At this period the value of the gas which escaped while lowering the bell was beginning to be more fully appreciated, and a number of devices were in use to prevent this waste, such as iron lids on the bell rod, which were so placed that the furnace hopper would be covered when the bell had reached the lowest point of its travel. With the advent of the skip hoist, the question of the proper distribution of the lumps and fines presented itself If the skip hoist with its many attendant advantages was to stay, some mechanical means must be devised for doing what had been easy of accomplishment under the hand-filling system. The evil effects of improper distribution were too many and too serious to be neglected.

With poor distribution, the results on the furnace would not be quite so bad were the chemical constituents of the fine and coarse materials approximately the same ; but poor physical distribution is always accompanied by poor chemical distribution. I will not attempt to discuss the question of thorough screening of coke and stone at this time, but it is the universal opinion of furnace operators that these two materials should be as free from dust and foreign material as is commercially possible to make them. The treatment and preparation of the raw materials are receiving more attention at the present time than ever before, and we should not undo some of the work that is being done along this line through faulty and improperly designed furnace tops.

If the materials charged into the blastfurnace were uniform in size and chemical analysis, and if, particularly, the ores were always of the same consistency as regards moisture, the problem of proper distribution would be easily solved. It is my opinion that ideal distribution, under present conditions, is attained when the materials comprised in any one charge of the furnace burden are so deposited in the furnace that physically and chemically any one sector is the exact counterpart of any other sector, and on any horizontal plane a sector of material shows the maximum fines at the periphery, and a diminution of fines and a corresponding increase of lumps towards the centre of the furnace.

Faulty distribution may take a form wherein an excess of the coarser materials is thrown to the walls and an excess of fines deposited towards the centre, which is usually repeated with every bell dumped. Under such conditions, the ascending gases will follow the lines of least resistance, and as the coarser materials are more easily penetrable, the gases, because of their tremendous reducing power and their high speed of travel, and by reason of the scouring action of the dust which they carry in ascending through the vertical ring, will cut the lining. If this is not promptly observed and corrected, economical operation is out of the question. This has been very closely watched, especially in later years, and often checked in time by the adjustment of one or more of the factors of distribution, resulting in better operation and longer life of the furnace. Such changes as these, wherein an attempt is made to correct some of the inherent defects of a faulty distribution, is dependent upon the closeness of observation of the operator, and when the effects of bad distribution manifest themselves, changes can be made which may correct the evil, but usually only after many trials and disappointments have been experienced. In some cases, however, the order of charging the materials has been changed, speed and angle of dump of the skip changed, and often where certain tuyeres showed the greatest activity and an excessive quantity of coarser materials, one or more of these very active tuyeres have been plugged, thus reducing the activity of that portion of the furnace. This latter course is only a makeshift measure and is merely an attempt to take care of a faulty distribution by an unequal wind distribution. It is but choosing the less of two evils. Under such conditions the bosh above the plugged tuyere or tuyeres will become inactive and allow an accumulation of half-reduced ore, coke, and stone, which in a short time becomes too heavy, slips into the hearth and chills the iron there in proportion to the amount precipitated. Also, when such faulty distribution exists, the coarse materials in the charge reach the tuyeres in a high state of reduction ; and the finer materials, which offer more resistance to the reducing gases, reach this zone in such a condition that the reduction must be completed by solid carbon, which means a tremendous endothermic action. Finer stone, with lower fluxing efficiency, and finer coke with lower calorific value, invariably accompany the finer ores. Thus at that portion of the furnace where we require the greatest amount of carbon to carry on the direct reduction and produce heat, we are not supplied with the agents for meeting the conditions.

In a case where it has been established that it is impossible to get a uniform distribution, we must make every effort to get as close to it as the equipment and the materials will permit ; and the furnace will have to be burdened in such a manner as to give assurance that the sections of the furnace giving trouble are supplied with the amount of fuel necessary to furnish the heat and reducing power (and also sufficient porosity in that section) to make a reasonable grade of iron. This is extravagant and wasteful and is adopted only as a last resort.

Faulty distribution increases the amount of flue dust more than any other cause, due to the vertical shearing action between the sides with the high and low percentages of fines. This in turn causes an irregular descent of the charge, thus creating a disturbance which permits the gases to pick up the finer materials and carry them into the flues. It also increases the top temperature, which is an indication of uneconomical operation. Should faulty distribution deposit too much fine material at the walls of the furnace, or in a ring concentric with the periphery of the furnace, evil equally as serious as those mentioned above but of a different nature result. It will be readily seen from this, then, that only as the distribution approaches the ideal can the blastfurnace approach the efficiency of which it is capable.

The question as to what are the main factors that have contributed to the more economical and efficient practice of the last few years has been frequently asked. As many and varied claims have been put forth, this is a most difficult question to answer. In my opinion, among the many other essential improvements, proper credit must be given to the better adjustment of the flexible factors of distribution, such as the dumping angle of the skip relative to the centre line of the furnace, speed of dumping, changes in the receiving hopper and skip, changes in the order of charging the material, the order of dumping both on the small and large bell, changes in the size and angle of the large bell, and other factors with which blastfurnace operators are familiar. The better mechanical preparation of the raw materials, through screening of the coke and stone and better mixing of the ores in the ore region, also contributed. These latter not only assist in the mechanical feature of distribution, but in the proper chemical distribution as well. I believe that the tendency of to-day to increase the diameter of the hearth and steepen the angle of the bosh, while not eliminating entirely the evils of poor distribution, tends in a great measure to counteract them. Beyond a doubt, the bosh conditions have been improved.

(*To be continued.*)

NOVEL DEVICE FOR CLEANING SHAFTING.

THERE has recently been patented by Mr. A. H. Townley, of 93, Cromwell Grove, Levenshulme, Manchester, a simple and novel device for keeping shafting clean. The device consists of a disc of leather board or similar material, coated with wax or other grease-proof preparation, and having a hole in the centre somewhat larger than the shaft to which it is applied. In order to enable it to be fitted on the shaft the disc is cut from the centre to the outside, after which it is fastened by means of a suitably designed clip. The action of the shafting revolving keeps the disc upright and causes it to travel from pulley boss to pulley boss or pedestal boss, and reverse automatically. By this means the oil or grease is evenly distributed and the shafting kept bright and free from rust.

Financial Facilities for Trade.—The President of the Board of Trade has appointed a Committee to consider the best means of meeting the needs of British firms after the war as regards financial facilities for trade, particularly with reference to the financing of large overseas contracts, and to prepare a detailed scheme for that purpose.

THE MANUFACTURE AND USE OF HIGH-SPEED STEEL.*

BY HENRY D. HIBBARD.

(*Concluded from page 6.*)

Theory of High-speed Steels. It has been found that the heating and cooling curves of high-speed steel are radically different from each other, and also that the cooling curve when the steel is cooled from 930° C. (1,706° Fah.) is greatly different from that when the steel is cooled from 1,250° C. (2,282° Fah.). When the steel is cooled from 930° C. the curve has an abrupt jog, which shows a great retardation in rate of cooling occurring between 700° C. and 750° C. (1,292° Fah. to 1,382° Fah.). The jog does not occur when the steel is cooled from 1,250° C., 320° higher, the line representing variations in rate of cooling being nearly straight. The rate of cooling to get these curves is slow, or at least not accelerated, and one cannot say what the curves would be like if the rate of cooling were hastened, as in quenching, but the curves obtained seem to throw much light on the question. The property of red hardness seems to be connected with the elimination of the great retardation mentioned.

The following explanation, based on the work of Carpenter and Edwards, of the properties of high-speed steels, seems to be helpful. Their researches on the heating and cooling of these steels have shown that such steels have an extraordinary stability of composition after they have been heated to 1,200° C. (2,192° Fah.) or more, and that a second heating of 550° C. (1,022° Fah.) has no softening or drawing effect. It seems fairly evident that red hardness depends on or is the natural result of these facts.

At a temperature higher than 1,200° C. (2,192° Fah.) a double carbide of chromium and tungsten is formed, which persists largely even when the steel is cooled slowly as in the open air, and more so when cooling is accelerated. This double carbide imparts to the steel a high degree of hardness and is stable at all temperatures up to 550° C. (1,022° Fah.) or somewhat higher. At 550° C. the steel has a low red colour visible in the dark.

If the above theory be true then at a temperature of 1,200° C. (2,192° Fah.) the chromium and tungsten must have a stronger affinity for carbon than iron has, whereas at lower temperatures, say from around 930° C. down to the critical point, the affinity of carbon for iron is slightly stronger than that of either chromium or tungsten or both, and the carbon then exists wholly or in part as carbide of iron, or a complex carbide of iron with one or both of the other elements. Carbide of iron, or hardening carbon which causes the hard condition of iron in simple steel that has been quenched from a temperature higher than the critical point, is unstable at even slight elevations of temperature above atmospheric temperature, its unstableness increasing with the degree of heat, though not being proportional thereto. It has been shown that between 400° C. (752° Fah.) and 500° C. (952° Fah.) the amount of change and consequent softening is much greater than at other temperatures, either lower or higher. The proportion of carbon in high-speed steel should perhaps be only as much as will combine with the chromium and tungsten at 1,200° C. (2,192° Fah.) and leave none to exist as unstable hardening carbon of hardened simple steel.

Testing and Using High-speed Steel.—A reliable and inexpensive method of quickly testing high-speed steels to show their value is much needed. Machines and methods that lessen the time and trouble of testing have been used and recommended, but no test seems to take the place of a trial at actual work, because the performance of a tool in one line of work with certain conditions may not be foretold positively by its performance in another with different conditions. Among the reasons are that (1) sometimes greater durability is obtained by changing, that is, increasing or lessening the speed of the cut, thus changing also the temperature of the tool, or (2) a given tool when used at its best speed may be excellent for cutting a certain material, yet prove inferior to another tool for cutting a different material. Thus if selected as the best by trial for cutting a 0·20 per cent. carbon steel it may be surpassed by others in cutting a 0·70 per cent carbon steel. Physical tests of high-speed steels at different temperatures up to 800° C. (1,472° Fah.) are needed to show the effect of heat on the physical properties of those steels. New uses would probably be suggested by the results of such a series of tests.

A high-speed steel tool does not finish the piece being cut as nicely as does a simple steel tool, as the high-speed steel does not keep a fine edge with a light cut and slow speed of, say, 20ft. per minute. The durability of such a tool taking a light cut is much greater at a higher cutting speed, at which the tool is hotter, showing that the strength or the toughness of the steel or both are augmented by the higher temperature. Unhardened simple steels with 0·6 to 0·7 per cent. carbon get stronger, but less ductile, with a rise of temperature up to about 300° C. (572° Fah.). If, as the temperature rises, high-speed steels get stronger without loss of ductility, but perhaps with an increase, within limits of course, a physical reason for their great durability is provided.

In 1910 there was announced the discovery that any high-speed steel tool and some simple steel tools may have two rather widely separated cutting speeds at which the tool is more durable than at speeds above, below, or between. Thus out of many cases described, one tool cooled in an air jet had nearly equal maximum durability at two speeds—50ft. and 90ft. per minute—whereas at 65ft. the durability was less than one-half of that at either of the other speeds. This discovery no doubt accounts for some of the anomalies encountered in tool steels as well as other steels, the properties or performances of which are not what would be expected from their composition and other attributes. Thus a tool may be condemned when an increase of its cutting speed would cause it to give satisfactory service and durability. High-speed steel will do its best cutting when hot. A desirable practice followed in some shops is to heat a tool to near redness before putting it to work.

Machine-tool Design.—When Taylor and White first introduced high-speed steels it was thought that the higher cutting speeds afforded constituted the sole benefit to be derived from them, and as the higher speeds, although consuming more power about in proportion to the increase in speed, did not increase materially the stresses on the machine tools, it was thought that the latter merely needed to be speeded up in order to get the full benefit from the new steels. But it was soon found that the high-speed steels, in addition to cutting at higher speeds, were capable of taking much heavier cuts, which proportionately increased the stresses on the tools. To take full advantage of the heavier as well as the more rapid cuts, machine tools were generally redesigned to provide the greater strength required, and were supplied with proportionately more power. The resulting economics all over the world have been enormous.

The advantages from the use of high-speed steels as compared with the use of simple tool steels are in the lessened costs of the ordinary operations of finishing iron and steel because of (1) more rapid cutting speed; (2) heavier chips cut, hence larger cuts and feeds; (3) saving of power per unit of metal cut off; (4) lower cost of plant for a given output; (5) lower general and overhead charges connected with manufacturing iron and steel products.

Patents on High-speed Steels.—Since the original Taylor and White patents for treatment of high-speed steels were issued in 1901, others have been granted for almost every possible combination of elements which were in any way thought to be useful or valuable constituents of tool steel. Chromium and tungsten were generally included, though not always. Nevertheless most makers now aim at substantially the same foundation composition, with varying amounts of vanadium and sometimes with cobalt.

Miscellaneous Uses of High-speed Steels.—An important use for high-speed steel is in the exhaust valves for automobile engines, where it has given excellent results. These valves operate sometimes at a red heat and seemingly the property of red hardness that the steel possesses enables it to give good service in these valves. High-speed steel is being used also in the manufacture of extruded brass to form the

* From a bulletin on "The Manufacture and Use of Alloy Steels," published by the United States Bureau of Mines.

die through which the extruded metal is forced. The temperature of the brass is high, near its fusion point, and seemingly the red hardness of the steel enables the steel to perform this service satisfactorily. A good file or a good cold chisel may be made of high-speed steel, but they are not good enough to justify their cost as compared with those made of simple steels.

NEW PATENTS.

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MECHANICAL, 1914.

Carburetters of internal combustion engines. Bailly. 12161.
Taps and cocks. Chavee. 16118.
Internal combustion engines. Bouteille. 17016.

1915.

Water softening and purifying apparatus. Paterson. 4275
Ships. Elia. 4296.
Pneumatic conveying plant. Bennis. 7505.
Puddling iron. Fletcher & Harrison. 7691.
Fire bars for the furnaces of steam boilers. Jenkins. 8906.
Partial admission turbines. Parsons, Cook, & Howe. 9005.
Recovery of zinc. Highfield. 9009.
Rack and pinion mechanism. Howarth. 9042.
Railway locomotives. Spencer. 9050.
Controlled reversing valve gear for steam engines. Corbridge. 9055.
Condensing steam turbine plants. Baumann. 9145.
Valves for pneumatic drills. Sir W. G. Armstrong, Whitworth, and Co., and Holt. 9268.
Hydraulic pressing apparatus. Schneider. 9291.
Hydraulic intensifiers. Schneider. 9292.
Lathes. Schellenbach. 9294.
Rotary engines, pumps, meters, and blowers. Lilly. 9359.
Apparatus for priming and starting internal combustion engines. Eureka Patent Gas Engine Starter Company, Willison, and Matthews. 9464.
Clamps for hoisting ropes. Koughan. 9495.
Production of metal castings in metal moulds. Jensen. 9513.
Moulding machines. Bixby. 10964.
Internal combustion engines. Lamplough. 11293.
Instrument for recording the deflections of bridges and girders. Rutter. 11351.
Governors. Hartnell. 11352.
Tube scrapers for fuel economisers. Lord. 11758.
Two stroke cycle internal combustion engines. Croset. 11881.
Apparatus for caulking and riveting. Scott. 12661.
Motor power plant. Selous. 12745.
Stamping presses. Waller. 12827.
Mechanism for converting rotary into reciprocating motion. Ames. 13060.
Reciprocating engines. Peppers & Marchese. 13245.
Method of manufacturing gear wheels. British Thomson Houston Company. 13286.
Power hammers. Mitton. 13288.
Safety valves. Cockburns, Ltd., Cockburn & MacNicoll. 13698 and 13699.
Two stroke internal combustion engines. Villiers Engineering Company, and Farrer. 13986.
Rock drills. Mauss. 14920.
Two stroke cycle internal combustion engines. Fornaca. 16006.
Holding bit for cutting circular holes in sheet metal. Say. 16723.
Couplings for railway vehicles. Unternahrer. 16859.
Method and means for cutting irregular gears. Fellows. 16796.
System of ship construction. Morton. 17098.
Liquid fuel furnaces. Yarrow. 17450.
Lancashire and Cornish boilers. Greaves & Brown. 18051.
Signalling apparatus for use in connection with winding engines at collieries. Bolton. 18198.

1916.

Car couplings. McConway & Torley Company. 749.
Gravity feed lubricator. Hedley, R., and Hedley, J. W. 1544.
Construction of tubulous heaters or coolers. Smith, L. E. 1585.
Construction of gas generating apparatus. Tredegars, Ltd., and Morris, J. M. 1604.
Process for the recovery of metals from tinning, galvanising, and like waste. Rothberg, M. E. 1863.
Valve-operating mechanism for internal-combustion engines. Reeves, A. W. 2778.
Vaporisers for internal-combustion engines. Dobbin, H., and Haydon, B. 2805.
Ball bearings. Soderlund, C. G., and Nordiska Kullager Aktiebolaget. 2813.
Variable speed gears. Welffens, E. J., and Renold, Ltd., Hans. 2964.
Clutches. Napier, D., & Son, and Rowledge, A. J. 3009.
Non conducting jackets for boilers. Hutsel, R. 3277.
Method of making pipe bends. Locomotive Superheater Company. 3355.
Ball bearings. Czech, S. L. 3464.
Refuse destructors. Southall, J. 3838.
Internal grinder for use in lathes, boring, drilling, milling, and other machine tools. Kershaw, H. 4263.
Tools for boring gun tubes or barrels. Worsley Mesnes Iron works, Ltd., and Bedford, W. H. 4306.
Piston packing. Reavell & Co., and Reavell, W. 4464.
Quick-opening vices. Martin, H. 6470.
Motor power plants. Westinghouse Machine Company. 6874.

ELECTRICAL, 1914.

Electric incandescent lamps. A B-C- Schriftlampen Ges. 7591.

1915.

Switches for use in ignition systems for internal combustion engines. Swyers. 1950.
Means for controlling electric motors. Akt. Ges. Brown, Boveri, et Cie. 4222.
Apparatus for measuring electric current. Landis & Gyr Akt.-Ges. 7341.
Electrical distributing system. Cole. 7457.
Wireless telegraph receivers. Marconi's Wireless Telegraph Company, and Wright. 8926.
Secondary battery plates. Electrical Power Storage Company, and Schofield. 9012.
Magnetos. Pedersen. 9054.
Automatic or semi automatic telephone systems. Relay Automatic Telephone Company. 9283.
Telephone systems. Automatic Telephone Manufacturing Company. 9396.
Vapour electric devices. British Thomson-Houston Company. 9960.
Primary cells. Wilkinson. 10137.
Ignition apparatus for use with internal combustion engines. Williams. 10585.
Flexible electric conductors. Downes. 10837.
Systems of control for electric motors. British Thomson-Houston Company. 11768.
Clamping devices for electrically conducting wires. Cuthbert. 13441.
Magnetos. Pedersen 14895, 14896, and 14898.
Electric rotary converters. Pieper & Pieper. 16933.
Current regulators for electric furnaces. Aktiebolaget Elektriska Ugnar. 17022.

1916.

Electric heat-regulating switch. Kiell, J., and Stow, A. A. 1707.

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,, tubes (brazed)	1/5¾ ,,
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,, ,, wire	1/4⅛ ,,
Copper, Standard	£87/–/– per ton.
Iron, Cleveland	82/6 ,,
,, Scotch	— ,,
Lead, English	£29/15/– ,,
,, Foreign (soft)	£27/15/– ,,
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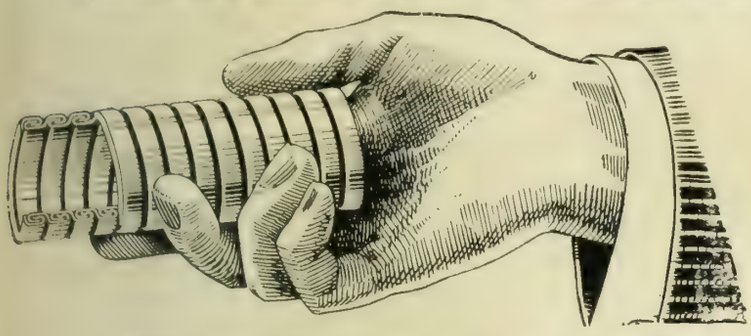

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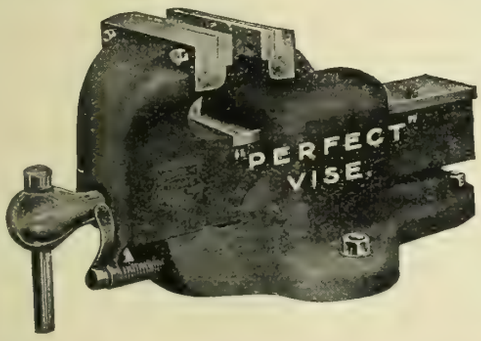

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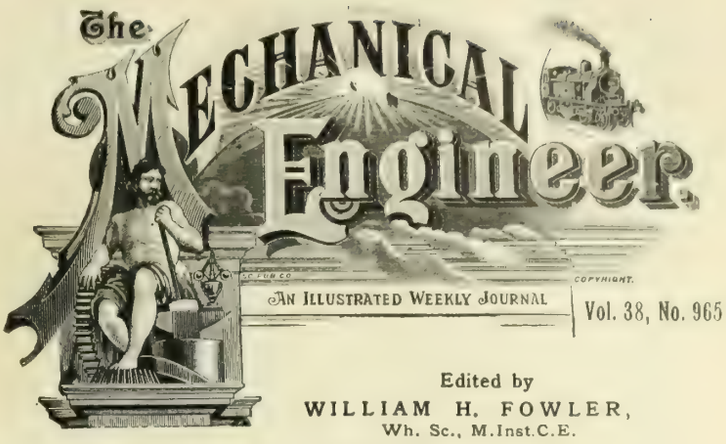

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Edited by
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Production After the War.

THE war has led to a great deal of national introspection, and in spite of the absorbing nature of the military contest thoughtful people are taking a large measure of interest in certain questions concerning the economics of trade and industry that will peremptorily demand attention when the war is concluded and the struggle for existence again depends on supremacy in the arts of peace. The last two years have destroyed numerous illusions and changed our outlook on many social questions. In face of a common danger, rich and poor, employer and workman, aristocrat and peasant, have found in the trenches a fraternity little suspected in pre-war days. The exercise of it has dissolved many prejudices and enabled great things to be accomplished, and it is to be hoped the welding process will not break down when the present supreme and united effort against a foreign foe is replaced by the more frequent, and sometimes opposed stresses, that spring out of class jealousies and prejudices in times of peace. The obliquity of character produced in Germany by a generation of false philosophy and military despotism has come as a shock, but if we have been spared this baleful influence our political system has not been free from defects. The name of liberty has been frequently misused in latter-day legislation, and gross license accorded to certain sections of the community by political parties eager for votes and power. Protection, when asked for by manufacturers, has been denounced as selfish class interest, but has been granted in full measure in worse form to trade unionists, with the power to strike and freedom from responsibility for their acts, with the right to refuse to work, and liberty to prevent others doing so by "peaceful" picketing. With licence granted in such wholesale measure it was little to be wondered at that restriction of output, *alias* "ca' canny," controlling the working of machines, repu-

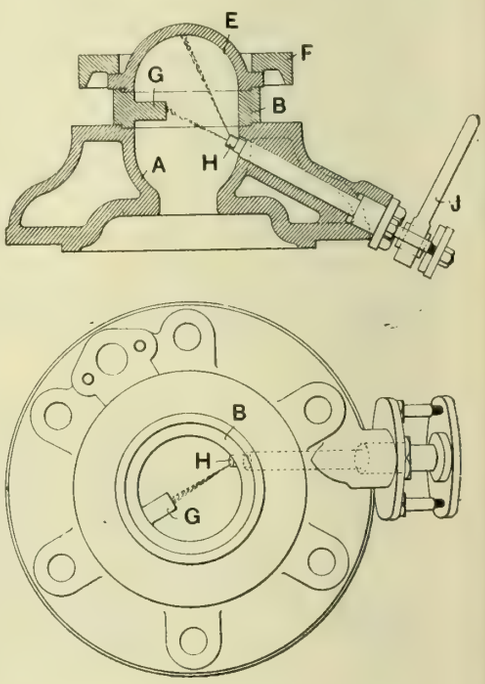
diation of agreements, refusal to accept arbitration awards, should become characteristic of trade disputes, or that the more reckless members of unions should often replace the more thoughtful ones as "leaders," or rather we ought to say "officials," for anarchy had become exalted, and there were not wanting powerful organs in the press, with exquisitely tender consciences for most things, ready to excuse or palliate every outrage against fair play and justice when committed by a trade union. We all know with what vigour and indignation these "rights and privileges" were defended when requests were made for labour dilution and greater output of munitions by men who were daily risking their lives for national liberty in the snow-sodden trenches of Flanders. It is hardly necessary to repeat this bit of history further, though it is desirable to remember that the unions have registered and docketed a claim to exercise these "rights and privileges" at the end of the war, that they are only suspended, not abrogated, and it is to be feared that unless countered by education and public discussion this claim will lead to a resumption of much bitter and senseless strife between capital and labour when their co-operation will be more than ever needed in the markets of the world. For this reason the ventilation of questions at issue between them is to be welcomed even amidst the din of battle. Two notable contributions of this kind have been made during the last week or two, deserving of a wider audience than that to which they were immediately addressed, and which we shall therefore take the liberty of reproducing,* and recommend our readers to carefully peruse. Mr. W. L. Hitchens, the chairman of Messrs. Cammell, Laird, & Co., at the National Economy Exhibition, devoted himself to a discussion of the importance of increased production, and showed how seriously limitation of output handicapped us in competition with other nations, and how misleading is the cry that freedom to produce means servitude to the producer. No one will contend that labour in America is servile by comparison with this country, and yet pre-war statistics showed that an average of two-and-a-half times as much work per working man was turned out in the States as in this country. The reason is not that the workman there is superior in skill, or possesses more energy, but that he has greater freedom to exercise it. There is an absence of the harassing rules imposed here by trade unions on the employment of machinery. Rules which have been so scathingly exposed in the official publications of the output of women and unskilled labourers in munition factories when allowed to work untrammelled, and which the unions openly declare they will again impose when the war is over unless prevented, as we trust they will be, by public opinion. Whilst trade union tyranny has been responsible for much of this restriction of output, stupid legislation has also something to answer for. In the United States it is commonly considered that machinery of many kinds becomes obsolete in five years, whereas in this country the income-tax laws only permit of its being wiped out in 20 years. These laws obviously become increasingly serious with income-tax at 5s. in the £, and loudly call for readjustment. The second address was given by Sir Hugh Bell before the United Workers, at the Princes Skating Club, on the 4th inst., and was devoted to a discussion of the fallacy so common amongst the workers, that in the division of profits they receive a very unfair proportion, and the capitalist receives an unduly large one. This erroneous belief is often expressed in unstrained language, and though facts and reason lend it no support it is hard to dispel. Its prevalence is, of course, like that of others, the result of ignorance, as Sir Hugh plainly shows. Far from receiving the lion's share of profit, capital often receives only a microscopical one, and not infrequently has to be content with none at all, or rest satisfied with the reflection that it has made the way to profit smoother for someone else. Ignorance is, in fact, the stumbling block to progress all along the line, and hand in hand with clearer conceptions of the true relations between capital and labour must come an improved system of education for the toilers of the next generation, on whom will fall the heavy obligation of paying, by increased effort and industry, the terrible legacy of debt which will be left when peace is restored.

* Pressure on our space compels us to hold these addresses over to our next issue.

GARDNER'S VAPORISER FOR OIL ENGINES.

In the case of 2-stroke cycle internal-combustion engines of the type in which the liquid fuel is injected into a bulb-like part wherein it is ignited, it has been proposed to provide a peg-like projection upon the inner surface of the bulb on to which the fuel, or—if two jets of different fuels are employed—the less readily ignitable fuel is directed, it being found that under certain conditions of working, such as when the engine is working under medium and heavy loads, vaporisation and combustion is more efficiently secured by the aid of this peg-like part. In practice, however, it is found exceedingly difficult to determine satisfactorily when the fuel jet is impinging upon the end of the peg, the jet orifice being of exceedingly small bore and the jet being readily deflected.

A simple and effective device for this purpose has been patented by Mr. E. Gardner, Barton Hall Engine Works, Patricroft, Manchester, and is illustrated herewith, Fig. 1 being a sectional view and Fig. 2 an end view of the vaporiser, with the dome portion and the holding-down ring removed. The hot bulb or vaporiser is of usual form but in three parts, an inner water-jacketed portion A, an intermediate ring-like element B seating in the portion A, and an outer dome E which seats in ring B, the ring and dome being clamped in place by the holding-down ring F. The peg-like projection G is provided on the intermediate ring B, on to the end of which the fuel is directed. By disposing the peg upon the ring B, which can be given a limited angular adjustment, the correct alignment of the injector H, and therefore of the jet and peg, is ensured, for the injector can be tried before the outer dome part is secured in position. The full advantages derived from the employment of the peg are thus obtainable. When the jet has been tested for alignment with the peg G, the stop limiting the movement of the jet-control handle J is brought against the handle, or the handle is adjusted to come against the stop, so that the adjustment of the jet for heavy loads is readily accomplished, it being only necessary to bring the control handle against the stop. For light loads the jet is directed into the unjacketed dome. The directions of the jet for heavy and for light loads are indicated in the drawings. Instead of employing a single fuel injector, two jets may be directed into the vaporiser, one jet of a readily ignitable fuel, being projected towards the dome and being timed slightly in advance of the other jet, which is directed upon the peg G and is of a fuel which will not readily ignite.



FIGS. 1 AND 2.
GARDNER'S VAPORISER FOR OIL ENGINES.

OIL ENGINES AND STEAM ENGINES IN COMBINATION.*

BY GEOFFREY PORTER, A.M.I.C.E.

My object is to discuss some of the problems met with in extending a comparatively—and in some instances, an extremely—inefficient generating station of the "lighting load" order, with a plant capacity round about 1,500 kw., and equipped with steam engines, some with condensers and some without. There are dozens of such stations dotted about the country, from 12 to 20 years old, none of them with any great future so far as can be seen at present, and most of them having difficulty to make ends meet financially.

Table I. gives various data relating to three generating stations, "A," "B," and "C"—"A" being my own, a small one on the South Coast; "B" a London station of considerable capacity; and "C" a riverside station in the provinces. It is not proposed to elaborate an ideal situation in this paper, but to deal with established facts, and to leave out of account all methods of providing additional plant except that of Diesel engines. The combination of steam and Diesel engines is now pretty well established, and reliable data are available.

Now, however, the Diesel engine is making good headway; manufacturers and users have gained experience, the fuel-oil question is in a fair way of being solved by utilising the products of the distillation of coal, and though the capital cost is and will probably continue to be high, the essence of the problem, *i.e.*, the balance in hand to credit of net revenue account in the annual balance sheet, is found to improve in proportion to the use of the Diesel engine. The mixed stations have justified the wisdom of their engineers during the present extremely difficult times; but for their efficient oil engines many of them would be in a bankrupt condition to-day.

In Table I. will be found the figures of the capital outlay on generating plant of the three stations already mentioned. The Diesel figures (capital costs) are stated in some detail, but time has not permitted the division of the steam plant costs under separate heads; they have therefore been taken as a gross total. (In my own station, "A," such sub-division has been possible, as the figures were got out for another purpose some time ago.) The items taken into consideration are engines and their dynamos, foundations, boilers, boiler settings, flues, chimney shafts, condensing plants, exhaust steam,

TABLE I.—Station A. 1043 KW D.C. Station B. 3700 KW. D.C. Station C. 1400 KW. A.C

	ITEM.	Last completed Financial year.		Last completed Financial year before starting Diesel Engines.		Last completed Financial year		Last completed Financial year before starting Diesel Engines		Last completed Financial year		Last completed Financial year before starting Diesel Engines	
		£	£ Per KW.	£	£ Per KW	£	£ Per KW	£	£ Per KW	£	£ Per KW	£	£ Per KW
1	Capital cost of Diesel Engines and Dynamos	8301	16·28	—	—	12,300	20·5	—	—	8450	15·35	—	
2	" " " " Foundations	200	39	—	—	2500	4·2	—	—	1277	2·37	—	—
3	" " " " Accessories	747	1·46	—	—	1200	2·0	—	—	506	0·94	—	—
4	Total " " "	9248	18·13	—	—	16 000	26·7	—	—	10,233	18·66	—	—
5	Total Kilowatts—Diesel Plant	510 KW	-	—	—	600 KW	—	—	—	540 KW	—	—	—
6	Capital cost of Steam Plant (Engines, Boilers, Accessories, including Foundations)	15,698	29·1	15,698	29·1	87.100	28·0	87,100	28·0	34,292	39·8	34,292	39·8
7	Total Kilowatts—Steam Plant	538 KW	—	538	—	3100 KW	—	3500 KW	—	860 KW	—	860	—
8	Capital Cost per KW. of combined Plant	—	23·9	—	—	—	27·8	—	—	—	31·8	—	—
9	Annual Insurance against Breakdown—Diesel Plant .. .	77	15	—	—	142	24	—	—	—	—	—	—
10	" " " " Steam Plant	58	11	58	·11	Boiler and Steam Pipes only 103	·033	103	·033	—	—	—	—
11	Annual Capital Charges (Interest and Redemption)	—	1·95	—	2·23	—	—	—	—	—	—	—	—
			Per KW hour Generated		Per KW hour Generated		Per KW hour Generated		Per KW hour Generated				Per KW hour Generated
12	Units Generated Diesel Plant	591,584	—	—	—	2,429,148	—	—	—	1,127,557	—	—	—
13	" " Steam Plant	11,312	—	609,609	—	2,133,214	—	5,024,127	—	403,431	—	1.332,851	—
14	" " . Total	602,896	—	609,609	—	4,562 362	—	5,024.127	--	1,530,988	—	1,332,851	—
15	Cost of Fuel per unit generated Combined Plant	—	·296d.	—	·570d.	—	459d	—	537d.	Oil 27 Coal 1·36	·594d.	—	869d.
16	" " Lubricating Oil, Waste Stores and Water	—	·106d.	—	·092d.	—	·032d.	—	028d.	—	·075d.	—	·048d.
17	" " Wages (Running Staff)	—	·139d.	—	·206d.	—	194d.	—	150d.	—	204d.	—	199d.
18	" " Repairs and Maintenance of Generating Plant	—	·073d.	—	·105d.	—	·090d.	—	106d.	—	·068d.	—	·060d.
19	" " Proportion of Salaries	—	·069d.	—	·068d.	--	—	—	—	—	—	—	—
20	" " Total Running Charges	—	·683d.	—	1·041d.	—	·775d.	—	·821d.	—	·941d.	—	1 176d.
21	Average Price of Fuel Oil, per ton	64/0	—	—	—	67/2	—	—	—	65/0	—	—	—
22	" " " Coal "	29/8	—	18/3	—	30/9	—	23/9	—	17/0	—	16/2	—
23	Units Generated by Steam Plant °/₀ of Total	2°/₀	—	100°/₀	—	47/2°/₀	—	100°/₀	—	26·4°/₀	—	100%	—
24	" " " Oil " " "	98°/₀	—	—	—	52·8°/₀	—	—	—	73·6°/₀	—	—	—
25	Units Generated per ton of coal	176	—	388	—	553	—	560	—	150	—	—	—
26	" " " oil	3200	—	—	—	3015	—	—	—	2435	—	—	—
27	Thermal Efficiency $\frac{\text{B.T.U. in units Gd} \times 100}{\text{B.T.U. in Fuel used}}$	22·6°/₀	—	4·93°/₀	—	Approx. 10·5°/₀	—	Approx. 6·1°/₀	—	Approx. 6·5°/₀	—	Approx. 2·6%	—
28	Coal used per unit generated	12·8 lbs.	—	5·8 lbs.	—	4·05 lbs.	—	4 lbs.	—	14·9 lbs.	—	10·1 lbs.	—
29	Fuel Oil " "	·67	—	—	—	62	—	—	—	92	—	—	—
30	Running Plant Load Factor Steam	69·4°/₀	—	66·2°/°	—	—	—	—	—	—	—	—	—
	Oil	56·9°/₀	—	—	—	—	—	—	—	—	—	—	—
31	Annual Load Factor	15·6°/₀	—	14·19°/₀	—	19·9°/₀	—	17·7°/₀	—	—	—	19·63%	—
32	Ratio price of Oil to price of Coal	2·14	—	—	—	2·16	—	—	—	3·82	—	—	—

* "B" and "C" include proportion of Salaries (see lines 17 and 19).

Some five or six years ago several papers were read before societies of standing in the engineering world, in which were discussed the advantages to be gained by the use of the Diesel engine. Some of the writers, I think, rather overstated their claims, and all conclusions were based chiefly on results obtained on the Continent with plant manufactured by continental firms. This was natural under the then circumstances, as few sources of information were available at the time in this country. The arguments, good as they were on the whole, fell on somewhat stony ground, for, with the Englishman's native scepticism of things foreign, engineers waited cautiously for an object-lesson in their own land.

Apart from this aspect of the case it was felt rather strongly that the best coal in the world is mined in the British Islands, while a residual petroleum fuel oil (with the exception of a limited supply of shale oil) is an imported commodity; hence, with a growing demand, the price of fuel oil would rise in a greater degree than would the price of coal. Further, from a business man's point of view, the Diesel engine requires a greater capital expenditure per unit of power than does an equivalent steam plant. The question of reliability in operation arose also, though I think it was used rather as an excuse than as a genuine argument in disfavour of the Diesel engine; for engineers cheerfully bought steam turbines in the early and middle stages of their development, and experienced a good deal of trouble with them—thus repeating the former experiences with electrical machinery.

and other feed-water heaters, feed pumps, oil separators, and the like. Left out of account are storage batteries, boosters, balancers, and all plant outside the works, as a comparison is sought only in the generating department.

It will be seen that the capital cost per kilowatt is high. This is due not only to the higher cost of plant at the beginning of the century, and even earlier, than in more recent years, but also to the piecemeal way in which generating plant has been added to from time to time. The engineer has always been over-weighted with the bulk of annual payments of interest and principal, and was compelled to arrange them in such a manner that the annual increments of such charges did not grow too disproportionately to the annual increments of income, which he could estimate fairly closely. The result has been the pursuit of a rather hand-to-mouth policy. When making extensions it would have been preferable, in the long run, to put down additional plant sufficient to supply the requirements of 10 years or so, from the ultimate financial point of view. However desirous one may be of taking and adopting long views circumstances are often too strong for us. The progress of an electric lighting undertaking lies along a straight and narrow way. The capital expenditure on the three stations up to the time when Diesel engines were put down was (for generating plant only) as follows, viz.:—

Station "A" ..... £29·1 per kilowatt.
" "B" ..... £28·0 " "
" "C" ..... £39·8 " "

* Paper read before the Diesel Engine Users' Association, June 23rd, 1916.

Stations "A" and "C" condense the exhaust steam; Station "B" is a non-condensing station. As the result of this large outlay the overall thermal efficiency of the three steam plants in the year prior to the adoption of Diesel engines was:—

Station "A"	.....	4·93 per cent.
,, "B"	.....	6·1 ,,
,, "C"	.....	2·6 ,,

These results are not very encouraging when one considers the money that has been put into the plant in each case. Nevertheless, the figures are typical in stations of their class. This thermal efficiency is arrived at by calculating the British thermal units equivalent to the units generated at the dynamo terminals (taking 3,412 B.T.U. per Board of Trade unit), and working out the total as a percentage of the British thermal units in the quantity of coal consumed. The figures given are not absolutely accurate owing to the heat values of the coals used not being certain, but I do not think they are very far wrong.

As one can speak most fully from one's own experience, I trust I may be forgiven if I analyse the various figures tabulated for Station "A." In 1911 extensions of plant became imperative; what had been done in the past and the possibilities of the future were very carefully considered. The capital expenditure on generating plant up to the end of the financial year 1910-11 was as under.

ENGINE-ROOM PLANT.

Engines, dynamos, and foundations ...	£4,690	£15·2 per kw.
Condensing plant and pipework	£3,506	

BOILER-HOUSE PLANT.

Boilers and their brick settings ..... (nominal evaporation 36,000lbs. per hour)	£3,602	£13·9 per kw.
Feed pump, injectors, and pipework...	£1,500	
Chimney, economiser, and flues	£2,400	
Gross capital expenditure		£29·1 per kw.

On this outlay the annual charges for interest and redemption of capital amounted to approximately £1,200, or £2·23 per kilowatt installed. On the other side of the account 1 kw. of maximum load on feeders produced (in 1910-11) 1,243 units, equivalent to about £21. Hence the capital charges on the steam-raising and using plant alone absorbed as much as 10 per cent. of the earnings. (Annual load factor 14·2 per cent.) Table II., line 18, shows a series of these figures. All the figures (except fuel figures) for 1915-16 are abnormal, owing to the various restrictions in force due to the state of war in which we find ourselves. The same remark would apply in a less degree to those of 1914-15.

After very careful consideration it was decided to extend the plant with Diesel engines. At the time an addition of 250 kw. was required. I decided to divide this capacity between two engines—first, because a better "running plant" load factor could be obtained in this way; and, secondly, from motives of caution. The type of engine was new to the staff, and I argued that it would be very unlikely for both engines to collapse at the same time should they prove unreliable in operation. I am glad to say that my caution turned out to be superfluous. Better and more consistent running could not be desired.

Station "B" has provided me with figures relating to the hours lost through defects in the year 1914-15, as follows:—

No. 1 engine.....12 hours.....piston trouble.
No. 2 engine.....12 hours.....high-pressure cooling coil worn.
No. 3 engine.....36 hours.....compressor trouble.

The capital cost of the extension worked out at £16·95 per kilowatt. Two years later a third engine was obtained, coupled to a 260 kw. dynamo, at a capital cost of £19·27 per kilowatt. In all, a capital expenditure of £18·13 per kilowatt for 510 kw. capacity.

Turning again to Table I. it will be seen that Station "B" spent £26·7 per kilowatt for 600 kw.; and Station "C" a sum of £18·66 per kilowatt for 540 kw. of plant. Local circumstances entailed a very heavy expense for foundations in the case of "B," while plant was more expensive in first cost than at the time when I was in the market. "B" profited by other people's experience in the matter of "accessories," and wisely spent rather more money on them—notably on fuel-oil storage tanks. "C" adopted engines and dynamos which required large foundations, with the result that the gross capital outlay was rather greater than it was in Station "A." An equivalent steam plant for "A" would have necessitated an outlay of £7,450, equivalent to £14·8 per kilowatt. The annual charges for interest and repayment of principal would have been £177 less for a steam plant than for a Diesel plant.

On a "running plant" load factor of 65 per cent., and with coal at about 13,000 B.T.U. per pound, I expected to produce 500 units, more or less, to a ton of coal—taking the whole steam plant into consideration. Enquiries in several quarters lead me to expect confidently that a Diesel engine under the same load-factor conditions would deliver 3,200 units per ton of fuel oil of 17,500 B.T.U. per pound. Assuming a price ratio of 2½ to one between oil and coal (as it was approximately for "A" in 1910 to 1911), there was a large margin in the earning capabilities of the two types of plant to cover the difference in the annual charges.

TABLE II.—*Station "A."*

	ITEM.	1910-11. Steam Only.	1912-13. Steam & Oil.	1913-14. Steam & Oil.	1915-16. Steam & Oil.	Estimate Steam Extension.
1	Fuel	·570d.	·454d.	·42d.	·296d.	·46d.
2	Wages (Running Staff)	206d.	·134d.	·12d.	·139d.	·20d.
3	Lubricating Oil, Waste Stores, Water...	·092d.	·074d.	·06d.	·106d.	·09d.
4	Repairs, Maintenance, Plant...	105d.	·041d.	·07d.	·073d.	·10d.
5	Proportion of Salaries...	·068d.	·055d.	·05d.	·069d.	·06d.
6	Total Cost per Unit Generated	1·041d.	·758d.	·72d.	·683d.	·91d.
7	% of Total Units by Steam Plant	100%	17·8%	20%	2%	100%
8	% of Total Units by Diesel Plant	—	82·2%	80%	98%	—
9	Units per Ton of Coal...	388	248	334	176	500
10	,, ,, Fuel Oil	—	3350	3180	3200	—
11	Thermal Efficiency % ...	4·93	12·34	12·78	22·6	6·5 (a)
12	Fuel per Unit Generated Coal ...	5·8 lbs.	7·9 lbs.	6·7 lbs.	12·8 lbs.	—
13	,, ,, Oil ...	—	·67 lbs.	·70 lbs.	·69 lbs.	—
13A	,, ,, Combined	—	1·94 lbs.	1·84 lbs.	·89 lbs.	—
14	Price of Coal per Ton (Av.)	18/3	23/6	23/0	29/8	—
15	,, Oil Fuel ,, ,,	—	69/0	80/0	64/0	—
16	Water Consumption per Unit Generated .	45 lbs.	—	—	—	36 lbs.
17	Water Consumption per 1 lb Coal	8·5 lbs.	from and at	212° F.	—	10 lbs.
18	Units Sold per Annum per Kilowatt of Maximum Load on Feeders	1243=£22	1270=£21	1331-£21·8	1363-£19·5	—
19	Running Plant Load Factor: Steam ...	66·2%	62·2%	56·7%	69·4%	—
	Diesel ...	—	71·0%	66·4%	56·9%	65%
20	Annual Load Factor ...	14·19%	15·19%	15·30%	15·58%	—

(a) Maximum observed with Oil Plant alone—28·73% over one week.

*NOTE.—The last column of this table is an estimate of the probable results, had Steam Plant been adopted instead of Oil Plant.

The figures shown in lines 9 and 10 in Table II. give a series of actual results for "A." The figures in lines 25 and 26 in Table I. show the actual results obtained in Stations "B" and "C" as well. The low figure in the records of "C" is accounted for by the fact that one of the pair of engines put down was a 2-stroke cycle machine. All engines in "A" and "B" were vertical 4-stroke cycle engines.

So much for a direct comparison between steam and oil. The problem was, however, complicated by the existence of the original steam plant, in conjunction with which the Diesel engines would be required to work. Undoubtedly the boldest course to adopt would have been to write off a part at least of the steam equipment. This plan was considered, but, in view of the very long loan period (which had still 15 years to

run), the sum required for the purpose was too great for the finances of the undertaking to bear. Had more steam plant been added to the old, and allowing for a much shorter loan period and a higher rate of interest, the annual combined capital charges would have amounted to £1·62 per kilowatt of plant. The earning powers of one kilowatt were not expected to increase. The total capital cost would have become £22·1 per kilowatt. The following returns give some important figures for "A":—

Year.	Revenue per Kilowatt of max. load.	Gross profit per Kilowatt of max. load.	
	£	£	
1910–11	21·2	11·3	Steam plant only.
1911–12	20·4	10·4	Part Diesel about 2 months.
1912–13	19·1	11·1	Diesel plant 82·2 per cent. of output
1913–14	20·0	11·8	" " 80 " "
1914–15	27·3	14·9	" " 91·7 " "
1915–16	23·2	14·1	" " 98 " "

In the first column the revenue per kilowatt of maximum demand of feeders was artificially increased by the fact of the maximum output falling off, during the last two periods owing to restrictions, more rapidly than did the number of units sold. In the second column the figures of gross profit were adversely affected by the steam "stand-by" charges, two boilers being kept up for the greater part of the time in case of Diesel engine failures. During the last two years in the table the boiler-house was entirely shut up, except for a month or so. There is no doubt that the efficient working of the Diesel engines effected a marked increase in the gross profit per kilowatt of maximum demand on the plant. In the year 1912-13 the tendency of the gross profit had begun to counteract the downward trend of the revenue curve. An examination of the figures quoted show that the lower cost of operating a Diesel engine plant quickly extinguishes the higher annual charges for capital, although in the case of "A" the steam plant has an advantage of £·33 per kilowatt in respect of capital charges.

Five years ago opinions differed as to the functions of a Diesel engine in a "mixed" station. Some said, "Work it for all it is worth and use the steam plant for peak-load and emergencies"; others said, "Run your steam plant all the time in order to keep down the preparation charge proportion, and use your oil plant for the peaks and emergencies, when its quick-starting and high-efficiency characteristics will be of the greatest advantage." I think it is now the general practice to work the Diesel engines "for all they are worth," and to keep the steam engines in reserve. At anyrate, that is my own practice. In Table II., lines 6, 7, and 8 illustrate the point fairly clearly, and may be read in conjunction with the thermal efficiencies given in line 11. Lines 12 and 13a indicate the effect of keeping boilers under steam for stand-by purposes.

In Table I. a comparison of the generating costs of the three stations before and after adopting Diesel engines is instructive.

"A" shows a reduction of ·358d. per unit generated;
"B" " " ·046d. " "
"C" " " ·276d. " "

these figures being obtained in the face of rising fuel prices. Similarly, the overall thermal efficiencies have improved as under:—

"A"—Thermal efficiency rose from 4·93% to 22·6%
"B" " " " 6·1% " 10·5%
"C" " " " 2·6% " 6·5%

These figures depend, of course, on the proportion of the units generated by oil as a percentage of the total units generated. "B" having a steam plant of five times the capacity of its oil installation was obviously unable to make so great a reduction as was "A," where the proportion was roughly 1 to 1; and "C" 1·6 to 1. The greatest reductions are in the items fuel, wages, and repairs. It should be pointed out that Stations "B" and "C" include in the "wages" item the proportion of "salaries" of the engineering staff which is stated separately in line 19 of Table I. for Station "A."

I refer you at this point to Table III., which shows the cost of fuel per unit generated for Station "A" at various load factors for the steam and oil sections of the plant. The pair of curves, Fig. 1, shows the comparison graphically. Coal cost 18s. 3d. per ton, fuel oil was at 64s. per ton. The figures are taken from the ordinary weekly records, and are the result of every-day running conditions. From approximately full load down to half load there is a drop of 6·3 per cent. in the steam figures, and over a corresponding series there is one of 20 per cent. in the oil figures.

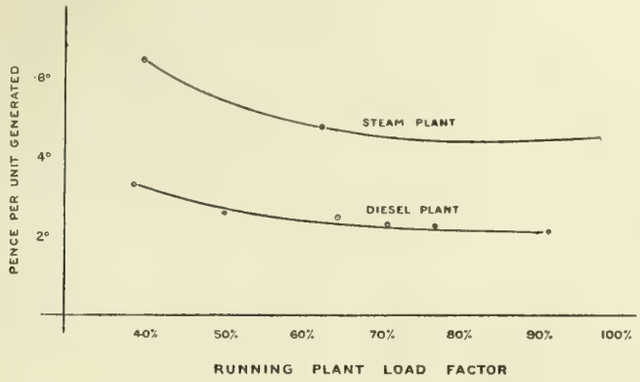


FIG. 1.

A statement of some of the "vital statistics" of eight generating stations having both steam and oil plants may be of interest; it shows a general tendency towards improvement in the financial position since the Diesel engine was adopted.

Station.	Reduction in fuel cost per unit sold.	Gross profit per kilowatt of maximum load before oil plant.	Gross profit per kilowatt of maximum load after adopting oil plant.
	d.	£	£
1	0·31	11·3	14·1
2	0·23	9·9	10·5
3	0·20	8·8	14·3
4	0·18	11·1	15·2
5	0·20	3·37	6·9
6	0·21	8·4	10·2
7	0·11	9·8	11·5
8	0·06	13·4	15·1

I regret that the figures in this table are not arranged on quite the same lines as are the figures in the other tables. In the time available I was unable to obtain the number of units generated in each case, hence the unit "sold" is here the basis of the calculation. The Diesel engine has this important advantage over the steam equipment. If valves are leaking and adjustments are not in order the fact becomes quickly obvious. The indications on the gauges (and there are not many of them) draw one's attention to irregularities. But a steam engine may run beautifully to the outward eye and ear although piston valves and piston rings may leak, and the valve settings may be wrong owing to eccentric strap wear; the boiler settings may be drawing many cubic feet of air into the flues; the fires may be too thick or too thin. In very many cases, provided the main steam gauge is showing about the correct steam pressure, there is a general feeling of satisfaction with the aspect of affairs.

Personally, I managed to improve the steam costs of "A" by 20 per cent. or so by the aid of flue thermometers, draught gauges, flue-gas analysers, and graduated staffs in the boiler feed-water tanks; but even at that the benefit was but a fraction of that gained by purchasing plant that was inherently more efficient from the thermal point of view. Putting the three things together, capital charges, running costs, and gross profits, the advantage accruing from the use of the Diesel engine for installations within the limits of those indicated in this paper is manifest. The figures quoted for "A" showed the combined annual capital charges for interest and redemption to be £1·95 for a mixed steam and oil plant, and £1·62 for a steam plant only, the difference being one of 20

per cent. Taking the running costs for the last completed financial year, the reduction in running costs from those obtained in pre-oil days was no less than 34·4 per cent.

In concluding this section of the paper I should like to urge on all Diesel engine users the great value of the indicator diagram as a quick and ready means of testing the condition of an engine. The "hand-drawn" cards are particularly valuable as showing the distribution of the fuel oil among the cylinders. If cards are taken and filed for reference and comparison, it is not difficult to keep an engine well up to its test results. The outlay of £10 to £15 on an indicator set is a small matter in comparison with the losses that may occur if an engine is not periodically checked.

The choice of the most suitable Diesel engine to accept when confronted with a number of them is not easy. All members of this association are now acquainted with the features which are and are not desirable in an engine. But, when taking the plunge in the first instance, the choice was difficult. Some engineers embraced the lowest tender with the affection frequently accorded to that interesting hybrid, others did not. Manufacturers' representatives were very kind, but exhibited a considerable admiration for the merits of their own particular variety of Diesel engine, and in this respect no other attitude could be looked for.

The attractions of the lowest tender are, of course, almost irresistible. In my judgment the lowest tender is suspect if it be more than 5 per cent. below the average of the other tenders. I do not venture to lay down any rule for the guidance of anyone in this matter, but I will go so far as to say that my own preference is for (1) a low piston speed; (2) a low mean effective pressure from the full load card; and (3) a low piston and crank-pin loading. The general design of the crankshaft and its bearings, the gudgeon pins, and the lubricating arrangements throughout must, of course, be examined also.

The transition from the paper stage to the practical one of operating the Diesel engine not unnaturally brought to light a number of occurrences with which engineers were not familiar. Many were trivial in their nature, others were serious. Many engineers solved their problems by means of their own skill, others grumbled and lost heart and interest. In course of time it was felt that a central body competent to collect and compile records and to act as a standardising authority to some extent was a necessity. In this way the Diesel Engine Users' Association came into being. From a very modest and quite informal beginning this association is growing steadily, and will, I trust, one day assume a very important position in the domain of the internal-combustion engine.

TABLE III.—*Comparative Fuel Costs per Unit Generated on a Load Factor Basis, extracted from the Weekly Records—Station "A."*

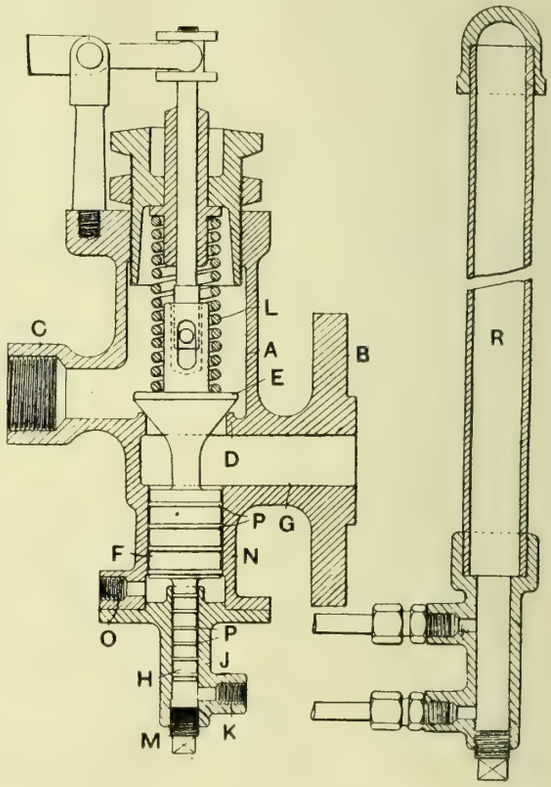
Running plant load factor per cent.	38·9	40·0	50·1	62·5	64·5	70·3	76·8	91·5	98·0
Steam plant pence	—	0·625	-	0·48	—	—	—	—	0·45
Diesel plant ,,	0·332	—	0·260	—	0·255	0·223	0·220	0·208	—

Coal at 18s. 3d. per ton; fuel oil at 64s. per ton.

PRESSURE RELIEF VALVE FOR PUMPS.

THE accompanying illustrations show a design of pressure relief valve of the type in which the valve itself is in complete equilibrium or balance by means of a piston in conjunction with the valve, and is adapted to be operated by an auxiliary piston connected with the main or other situation, the pressure in which is to be controlled. The valve, which is the invention of the Worthington Pump Company, Ltd., India House, Kingsway, London, W.C., and Mr. E. O. Rodaway, is particularly applicable for use with pumps.

Referring to the illustrations, the usual valve body A is provided, having inlet and outlet branches B, C, and a valve seat D, between them in conjunction with which the valve E is adapted to operate, the valve being formed with an extension F in the form of a piston, one face of which is in communication with the inlet passage G and the area of which is so proportioned that the pressure acting on one face of the valve E and upon the opposed face of the piston F, maintains the valve normally in a condition of complete equilibrium or balance. The balance piston F is provided with an extension H, forming an auxiliary piston of much smaller area working within a cylinder J, which is connected by a by-pass fitted to the connection K with the main or delivery branch of the pump, the pressure in which is to be controlled, the arrangement being such that the operation of the valve itself is effected by the pressure acting upon the small auxiliary piston H, the valve being arranged to be opened against the action of a spring L. The thrust of the auxiliary piston H which operates the valve is proportional to the pressure in the main or delivery branch of the pump with which the



PRESSURE RELIEF VALVE FOR PUMPS.

auxiliary piston chamber J is in communication, and as it is obvious that the effort required to operate the valve and consequently the load upon the spring L may be kept small, the compression rate of the spring L can very conveniently be selected such as to ensure complete relief with a minimum accumulation of pressure.

Since there is but very slight flow or motion of the substance in the pressure-communicating passage between the situation being controlled and the auxiliary piston chamber J, the bore of this pressure-communicating passage is very small and is formed of a small-bore pipe to which is connected where necessary a small air vessel R, as shown in Fig. 2. Such air vessel forms an effective cushion and prevents any shocks or rapid pressure fluctuation—the elimination of which may be impracticable or unimportant in the main pump delivery or other situation to be controlled—from being communicated to the auxiliary or operating piston H, thus ensuring smooth operation of the valve. The chamber within which the auxiliary piston operates is provided with a drain plug M for emptying if required, and the balance piston chamber N is also provided with an outlet O for connection to a drain or to the suction side of the pump in order to prevent any accumulation of pressure in the chamber N such as might occur due to leakage past the balance piston F or the auxiliary piston H. Both pistons are provided with piston rings P in order to reduce such possible leakage to a minimum.

BOILER-HOUSE DESIGN AND OPERATION.*

BY W. W. LACKIE.†

THE design, equipment, and operation of a boiler-house in connection with an electricity generating station invite attention to a variety of quite distinct engineering problems, almost any one of which would require a paper to itself. In the time at our disposal attention will necessarily be confined to a general survey of the boiler-house as a whole. Many considerations have now to be kept in view in the design of a modern boiler-house, but the main object has come to be to have the maximum of steaming capacity in the minimum of space. The necessity for this has largely been brought about by the introduction of turbine-driven generators and the ever-increasing size of generating sets. Twenty years ago, in the design of a generating station, it was a simple matter to install an additional boiler for each addition to the engine-room plant, as a reciprocating engine of 500 h.p., or even 1,000 h.p., with its generator occupied practically the same amount of space as the boiler plant required to supply steam to such sets.

In these early stations the area occupied by the boiler-house was practically the same as the area necessary for the engine-room, and extensions were easily made. On account of the poor load factor which prevailed in these stations, due to the fact that the demand was mainly for lighting supplies, the limited area of supply, and the central site chosen for the station, economisers were seldom installed and the stations were run non-condensing. The power per square foot in the engine-room varied, but 1 h.p. per square foot of engine-room floor space was an average figure. The boiler-house was, as a rule, a one-storey building, and an evaporation of 14lbs. of steam per square foot of boiler-house floor space, or 42lbs. per square foot of boiler floor space, was the steaming capacity. This was considered a good average figure. The boilers were hand-fired and the coal store was the floor in front of the boiler or a bunker in front of and practically on the same level as the boiler. All ashes had to be removed by hand on to the boiler-house floor or direct into hand-barrows, to be wheeled away at any convenient time.

A few years later, when it began to be recognised that the supply of electrical energy for power purposes was an economic possibility and larger stations were being erected, the power per square foot of engine-room space per horse-power was not seriously increased, as condensing engines were installed, and the space required for condensers increased the size of the engine-room and increased the total space occupied by the steam-using plant. Larger boilers were used, but economisers were then installed, and these were, as a rule, on the boiler-house floor level, and the evaporation per square foot of boiler-house space was not seriously increased.

The further growth in the demand for electric energy, the much improved load factor, and the introduction of the use of the steam turbine for the driving of electric generators about the year 1904, brought about a distinct change in the relative space required for engine-room plant and boiler-house plant. The turbine-room came to consist of a two-storey building, the condensers being on the ground floor or basement floor, and the turbo-generators on a floor above. Instead of having 1 h.p. per square foot of engine-room floor space, we have to-day turbine-rooms with 5 h.p. per square foot, and in designs for new power stations, using 15,000 kw. to 30,000 kw. sets, this figure may go up to 20 h.p. per square foot of engine or turbine-room floor space. With this enormous increase of power per square foot of turbine-room, changes in boiler-house design are absolutely imperative, particularly in the lay-out of the boilers, otherwise the space occupied by the boiler-house will be out of all proportion to the space allotted to the turbine-room.

It is now recognised that even with improvements in boiler-house design, where very large turbo-generators are in use, every pair of such sets requires a separate boiler-house. Several present-day power-houses have an evaporation of 50lbs. of water from and at 212° Fah. per square foot of ground space occupied by the boilers, but it is possible with improved design of the boiler-house plant to approach an evaporation of 100lbs. from and at 212° Fah. per square foot of the ground space actually occupied by the boilers. We therefore find that while the engine-room floor space and the boiler-house floor space were 20 years ago about equal, and remained so even for 10 years thereafter, to-day in a large modern generating station the ground space occupied by the boiler-house is from 1½ to 2½ times the space occupied by the turbine-room.

The first consideration is to ensure the maximum grate area per square foot of boiler-house floor space, and it appears that burning coal with natural or induced draught at from 25lbs. to 30lbs. per square foot of grate area there is a limit to the maximum possible continuous output per square foot of grate area, and that consequently there is a limit to the maximum power per square foot of boiler-house floor space. Arranging the boilers and economisers all on one floor practically doubles the area of the boiler-house; and in a modern boiler-house anything which adds to the area is to be avoided wherever possible. It is in fact now recognised that a modern boiler-house should consist of three storeys at least: the basement or ground floor containing ash-handling plant, the second floor containing the boilers proper, and the third or upper floor containing economisers and coal-conveying machinery and probably coal storage in the form of overhead hoppers above the boilers. Draught fans may be placed on any one of the three floors.

The question of chimneys and chimney draughts is by no means settled, but in stations where boilers of 50,000lbs. capacity are installed it is necessary to erect a separate chimney for each boiler or each pair of boilers. One is practically compelled to adopt steel in preference to brick for chimneys in a modern boiler-house, as with steel the chimney can be erected from the third floor, on which the economisers are placed, whereas if brick is used foundations have to be laid on the basement or ground floor and the structure continued to the third floors, at which point only it comes into useful commission. The brick chimney foundations and superstructure up to the second floor simply mean a waste of valuable space and a mass of brickwork which serves no useful purpose.

It is desirable not only to deal with ashes ejected from the boilers, but also to deal with riddlings and any semi-burned fuel. These riddlings have to be returned to the coal-conveying plant and thence to the overhead coal-hoppers, so as to be used again in the furnace.

The necessity for concentration of power has made the water-tube boiler indispensable for the modern power-house. The evaporative capacity of any boiler depends upon the grate area, or, in other words, the quantity of coal which can be burned underneath it, and consequently the maximum concentration of power is obtained when the whole of the generating and recuperating surface is assembled directly over the grate. Even with this type of plant the assembling of the heating surface over the grate area is undergoing modifications in order that the highest possible evaporation per square foot of ground space may be obtained.

The space actually occupied by boilers at present, with the necessary passages between, does not as a rule exceed 33 per cent. of the total boiler-house floor space, and of this 33 per cent. the grate area only accounts for one-half.

Let us consider the case of a boiler-house which has to supply steam to two 15,000 kw. sets. The steam required for each set will amount to between 180,000lbs. and 200,000lbs. of superheated steam per hour. This steam under modern conditions would be supplied by four boilers, each capable of generating 50,000lbs. of steam. Each boiler will require to burn at least 7,000lbs. of coal per hour, depending upon the calorific value of the coal. This means that grates of 250 sq. ft. to 270 sq. ft. will be necessary. A grate area of 250 sq. ft. means that each boiler will actually occupy, with passages between, about 500 sq. ft., eight boilers will require 4,000 sq. ft., and the boiler-house will have a floor area of 12,000 sq. ft.

From what has been said it is clear that increasing the size of the boiler unit will not of itself seriously increase the power per square foot of floor space. Twenty years ago water-tube boilers of 4,000 sq. ft. to 6,000 sq. ft. heating surface were considered large. To-day boilers are made with a heating surface from 10,000 sq. ft. to 20,000 sq. ft. In Detroit five boilers each with over 20,000 sq. ft. heating surface are in use.

The plan of installing boilers (apart from economisers) on two floors ought only to be adopted where the exigencies of the site render such an arrangement inevitable; that is to say, where land is dear or where local building regulations limit the

* Abstract of paper read before the Incorporated Municipal Electrical Association, June 22nd, 1916.

† Engineer and Manager, Glasgow Corporation Electricity Department.

dimensions of buildings in certain areas. In the new station of the United Electric Light and Power Company at 201st Street, New York (notwithstanding that this district is a suburb of New York) the company have been forced to adopt the flatted arrangement for their boiler-house in order to comply with city requirements.

The boiler-house must no longer be a stokehold with an atmosphere of grime and dust and dirt. It should be designed to admit of an ample supply of natural daylight. This is managed by placing the boilers back to back instead of face to face, with a firing floor down each side instead of down the middle between the two rows of boilers. Light can then be had from windows in the side walls as well as from the roof. This, however, means a larger floor area and a space between parallel boiler-houses, and further increases the ground area occupied by the power station. Adequate daylight can be got from roof lights with proper design of the roof.

There is still a tendency to-day to construct the combustion chamber of boilers much too small. A combustion chamber should be of such dimensions as to allow ample space for complete combustion taking place and the products of combustion thoroughly mixing before coming on to the heating surface. The author finds that the older boilers had 2 cub. ft. to 2½ cub. ft. of combustion chamber per square foot of grate area. To-day similar boilers have 5 cub. ft. of combustion chamber per square foot of grate area. The Detroit boilers before referred to have 9 cub. ft. per square foot of grate area, and it is generally conceded that this fact is very largely responsible for the high efficiency of these boilers at widely varying loads.

It is not necessary to enter into the details of the usual fittings of boilers, such as safety valves, high and low water alarums, dial steam-pressure gauges and miscellaneous valves; but it may be said that the equipment of a modern boiler should include two draught gauges. One of these should show the difference in pressure between the combustion chamber and the outlet from the boiler, *i.e.*, the difference in pressure across the boiler elements. This will be a measure of the flow of the gases through the boiler and will indicate when a boiler requires cleaning. The second draught gauge should show the difference of pressure between the ash-pit and the outlet of the boiler. This second gauge will always read higher than the first, and the difference is obviously a measure of the draught through the fire. Steam-flow meters are as necessary on boilers as an ammeter is on a generator, as they indicate what each boiler is doing, and whether all the boilers are doing their fair proportion of the work. One or more CO_2 recorders have been for some years installed as part of boiler-house equipment, and these are found to be a valuable adjunct, as they are an index of the working efficiency of the boiler-house. A word of warning, however, is required against assuming that high CO_2 always means high efficiency. There may be a large quantity of CO present. There should be thermometers or pyrometers with dial face on every boiler, giving the temperature of the superheated steam leaving the boiler, also the temperature of the gases at the damper.

With boilers of the size under discussion, steam piping should be carried from each boiler or pair of boilers to a steam drum or receiver placed on the boiler-house floor or basement floor adjacent to the wall between the boiler-house and the turbine-room. This arrangement is preferable to one large steam header. From the steam receiver a steam pipe is led to a turbine and another pipe to the next receiver, so as to give interchange of steam from one set of boilers to another when required.

We may at an early date see an increase in the boiler pressure from 160lbs. and 200lbs. to 250lbs. The Commonwealth Edison Company, of Chicago, worked the boilers in their Fiske Street station at 200lbs. until 1907, when they adopted 225lbs. at their Quarry Street station, and in 1910 they adopted 250lbs. at their North-West station.

A station of 50,000 kw. capacity and burning 200,000 tons of coal per annum requires coal-handling facilities for a supply of 1,000 tons of coal per day, together with facilities for the handling of ashes to the extent of 100 tons per day. This means a railway siding capable of holding from 100 to 120 full trucks, and probably another siding of equal dimensions to hold the empty trucks. The provision of an adequate railway siding is therefore a costly adjunct in the lay-out of a large power house owing to the serious addition to the site which it entails. The length of railway sidings for a 50,000 kw. station would not be less than half a mile, or an addition to the site equivalent to 4,400 sq. yards. The wagons have to be tipped and coal-conveying plant has to be provided capable of handling 100 tons per hour. Coal-breaking machinery should be installed, for while we have in the past been in the habit of using small coal, circumstances may in the near future render it economical to buy and break larger coal. This question, however, brings in the whole question of mechanical stokers, and that subject would require a paper to itself.

Large coal storage accommodation is advisable and will prove economical. Not less than from two to four months' fuel supply should be retained. This marginal stock enables coal to be delivered in fairly regular quantities throughout the year and may result in lowering coal prices. The height or depth at which coal can be stored depends upon the class of coal, and the best method of storing coal is still undecided. The cost of lifting coal from canal barges or from trucks, and placing it overhead in coal-hoppers or in the coal store, is a small item in the total price of coal. In one Glasgow station we have a coal transporter fitted with a 1-ton grab. This transporter cost £2,600, and it handles coal at the rate of 40 tons per hour, and the cost of energy, labour, and repairs on it brings the cost of handling coal in this way to just under 1d. per ton. In another station truck-loads of coal are elevated 30ft. at one end of the coal store to an overhead platform, whence the coal is tipped into an overhead hopper or to the coal store, and the empty trucks lowered by a second elevator at the other end of the coal store. These two elevators, complete with electrically-operated capstans, cost £2,000. The inclusive cost of handling coal in this way is 3¼d. per ton, the higher cost being due to the amount of labour necessary for handling the trucks. These figures are conclusively in favour of the grab and transporter. Where coal has to be carried a short distance from coal store to boiler-house, bucket or tray conveyors appear to be the right thing. On the other hand, for longer distances, the telpherage system works out slightly cheaper, although the human element, with its attendant problems, enters more largely into the telpherage system.

For the removal of ashes, bucket conveyors have proved to be costly in upkeep on account of the wear of the axles and pulleys, caused by the fine, hard grit of ash dust; but even with this drawback, bucket or tray conveyors seem to be the cheapest method of removing ashes. Suction ash plant is finding much favour on account of the absence of moving parts in its design, but the capital cost is very much greater (about three times) than that of bucket conveyors. Suction plants have not yet been long enough in use to warrant any definite pronouncement being made as to the repair bill. The cost for operating suction ash plant works out at about 5d. per ton handled, with energy at 1d. per Board of Trade unit. Suction plant is now made to do other work. It can be constructed for the purpose of elevating riddlings and small unburned fuel to a hopper or tank over the coal-conveying plant. It can also be made suitable for the removal of soot from economiser soot chambers and flue dust from the base of the chimneys. The efficiency of the ordinary vacuum cleaner is well known, and it appears that suction plant should be quite successful for the handling of this lighter material. The atmosphere in which all these operations are carried on is greatly improved by the action of the vacuum plant.

A modern boiler-house calls for comparatively large overhead ash storage, from which ashes can be dropped into wagons or other vehicles for their removal to a coup. The removal and disposal of ashes is becoming a serious matter. A few years ago ashes had a market value and we could get as much as 4d. or 5d. a ton for them. Then a time came when we were glad to get rid of them free of charge. To-day we have difficulty in getting the ashes from our stations carted away at 2s. a ton, paid to the carting contractor who undertakes their removal. It has been suggested that it would pay the large electrical undertakings to purchase 3-ton or 5-ton electrically-propelled wagons for the removal of ashes, especially where convenient railway facilities are not available.

Coal-weighing machinery for each boiler or group of boilers is absolutely necessary if proper records are to be made of the boiler-house efficiency. It should always be possible to ascertain the amount of coal used in each 8-hour shift and at the end of each week or month, so that the coal used per

kilowatt-hour generated may be ascertainable. These weighing machines should preferably be fixed between the overhead coal hopper and the boiler stoker, but some stations in America have a travelling gantry, fitted with a weighing machine at each end, the gantry travelling along the whole length of the boiler house between two rows of boilers. The duty of the operator on this gantry is to move up and down the boiler-house and to weigh out regularly to each boiler a predetermined amount of fuel.

Feed pumps may either be of the direct-acting type or centrifugal, although experience with the former is so good and repairs so low that it will be difficult to displace them. The total condensate from the turbine-room condensers should be measured by a Lea or other water recorder, and this should have an integrating attachment.

Having ascertained the amount of coal used and having measured the condensate, we can get the amount of water evaporated per pound of coal used. No very great increase in the efficiency of steam boilers can be looked for. The heat balance of many of the steam plants in operation at the present day is as follows:—

Heat absorbed by boilers	78 per cent.
Heat lost in flue gases	15·5 „
Heat lost in radiation and unaccounted for	6·5 „

That is to say, the total loss on which any reduction can take place is 22 per cent., but it is only a small proportion of this figure which can be attacked with a view to lowering it. It would be doing negative work to discharge the gases from a boiler at a temperature lower than that of the water in the boiler.

An evaporation of 4lbs. of water per square foot of heating surface in the boiler was, until recently, considered standard practice, but to-day water-tube boilers are designed, in conjunction with special economisers, to evaporate at the rate of 6lbs. normal load, and at overload 8lbs. and even 10lbs. per square foot of heating surface of the boiler. The heating area in most water-tube land boilers is of the order of 50 times that of the grate area. With such proportions the general practice is to emit the gases from the boilers at a temperature 500° to 550° Fah., *i.e.*, from 100° to 150° Fah. above the temperature of the steam at the boiler working pressure. The proportion of heating surface in economiser to heating surface in boiler varies in nearly every station, but the figure of 35 per cent. may be taken as a fair average. With such a proportion, allowing for heat drop in flues, the gases at the outlet to the chimney will have a temperature of from 325° to 350° Fah., and the economiser will have utilised about 7 per cent. of the heat of the gases emitted from the boiler. The inlet water to the economiser from the hot-well will, with present-day practice, be raised to a temperature of 200° or 220° Fah. Until recently the evaporation per square foot of heating surface of boiler and economiser combined was therefore roughly 3lbs. per square foot of heating surface. Modern practice tends to diminish the heating surface in the boiler from 50 times the grate area to 35 times the grate area and to increase the area of the economiser to 80 per cent. of that of the boiler heating surface. The result is to put up the evaporation of the boiler at overloads to 8lbs. per square foot of heating surface, and the temperature of the gases now emitted from the boiler is considerably raised, being about 650° Fah. The heat, however, is taken up in the economiser and the temperature of the feed water to the boiler is considerably increased. The net result is that we get an evaporation of 4½lbs. per square foot of heating surface of boiler and economiser combined. The overhead economiser is suitably proportioned to give the very highest combined efficiency. Boiler plants arranged in this way probably give a higher efficiency than was the case with previous designs, inasmuch as the radiation losses are less and the loss between the boiler and the economiser is reduced to an absolute minimum. The modern tendency is, therefore, to supply feed water to boilers at a temperature as near as possible to the temperature of the water already in the boiler, and the boiler simply adds latent heat and superheat to the steam. Each boiler has its own economiser and the economiser is really an integral part of the boiler unit.

An electric power station is simply a factory for the conversion of the chemical energy in coal into electrical energy. Coal is therefore the raw material of the factory; and as the final product, alike as regards reliability and price, depends first and last upon the quality and the regularity of the supply of coal, the selection and purchase of fuel are matters of the most vital importance. The selection and purchase of fuel is a question naturally dependent upon the geographical position of the site relative to the nearest coalfields, and upon the nature of the load. Power stations near the coalfields can use low grade fuel with resultant saving in the coal bill, whereas it is often more economical to use high-grade fuel in stations remote from the coalfields, as the same freight has to be paid for ash as for carbon.

The kind of fuel also depends upon the nature of the load, as it is a recognised fact that a higher overload duty can be obtained from a boiler fired with good-quality coal with a given draught than can be got with low-grade fuel. If a station has a purely lighting load, and consequently a low load factor, a larger number of reserve boilers with their resultant radiation losses, &c., have to be kept under steam to meet any sudden peak loads than would be the case in a power station where the load is chiefly for power purposes, and consequently the load factor is high. In the former case it is often more economical to use the best coal, because, with the higher overload thus made possible, the number of spare boilers can be kept down to a minimum.

It is now almost universal practice to buy fuel on a calorific basis, but it must always be remembered that along with calorific value and analysis there are to be taken into account physical properties. For instance, two samples of coal may show an approximately similar calorific value figure and present wide differences of behaviour in the furnace. Actual boiler tests must therefore be made with sample truck-loads of coal if the best and most economical selection is to be made. Anthracite coal with very high calorific value will only burn economically at the rate of 8lbs. to 10lbs. per square foot. I would certainly not advocate a slavish adoption of the calorific value basis in the purchase of coal, for the simple reason that coal is not a manufactured article, but a natural product, and if we are to hold the colliery owner or his agent responsible for its calorific value, he will undoubtedly, and quite properly, cover himself by increasing the price accordingly; whereas if the coal contractor is not tied down, the customer is sharing the risk inseparable from a natural product. The contractor can be and should be generally tied down to supply from particular pits. In the Glasgow Corporation Electricity Department the calorific value of the different kinds of coal offered is judged by the previous year's experience, and if any particular kind of coal as delivered is below our previous year's experience of it, then that coal has a decreased figure of value allotted to it against the time when next it will be again offered.

A practical test in a boiler specially equipped for the purpose is a very reliable guide to calorific value. The results of such tests should be reduced to a common basis. A good unit of comparison is the cost of evaporation of 1,000lbs. of water from and at 212° Fah., or the number of pounds of water evaporated for a pennyworth of coal, including coal and ash handling, which varies with the quality of the coal. It is usual to express the coal economic result for the whole station in pounds of coal per kilowatt-hour generated at the switchboard, but as this must obviously vary with the calorific value of the coal and the steam consumption of the engine or turbine plant, the better unit to use for general comparison is the British thermal unit per watt-hour, *i.e.*,

$$\frac{\text{pounds of coal per unit} \times \text{B.Th.U. in coal as fired}}{1{,}000}$$

Even this is not perfect, as it does not allow for the variation in load factor between different power stations, but it does enable comparisons to be made irrespective of variations in calorific value. In the two Victoria Falls power stations the economic result obtained in the way proposed gave in one station 27 B.Th.U. per watt-hour and in another 26 B.Th.U. Both of these stations had very high load factors, whereas in many of the London stations, where the lighting load is predominant, the average result is in the neighbourhood of 40 B.Th.U. per watt-hour. Daily samples of coal, as delivered, should be sent to the laboratory of the undertaking for calorific analysis. An assistant, working with a bomb calorimeter, can test 12 samples a day working from 9 to 1 and from 2 to 5 o'clock. These tests are recorded in a coal test book

for reference. As the results of tests obtained by any or all of the methods above referred to are tabulated and arranged, an index of the pits in the coalfield, from which the fuel supply is mainly or wholly drawn, can be compiled, and coal prices as received can be equated on a calorific value basis.

An interesting experiment has been carried out in one of the Glasgow gas works recently. Gas-coke breeze or gas-coke riddlings were burned successfully on chain-grate stokers with forced draught. A special form of arch had to be built. This breeze can be bought at 20 per cent. the price of coal and it has a calorific value of at least 60 per cent. of coal. There is a large amount of ash, but the experiment went to show that with intelligent superintendence good results could be obtained with this class of fuel, although the actual output of the boiler was considerably reduced.

With regard to the whole question of fuel, experience seems to show that it is preferable to buy the best, for while good results may be obtained with inferior fuel, careful and constant attention to the fires is necessary with such fuel, whereas with first-quality fuel very little attention is required.

Twenty years ago a fireman in a generating station was truly a fireman. Stripped to the waist, he had in many cases to lift every pound of coal from the floor level to the furnace door. He had to be continually opening and shutting furnace doors and stirring up the fire. At regular intervals he had to bear excessive heat and noxious fumes, removing ashes from the furnace, which had thereafter to be wheeled away or shovelled direct into carts. It was no uncommon thing in such a boiler-house to have the fireman boasting that he had tackled the load with three boilers, whereas he might have saved both labour and fuel by having four boilers going.

All this has been or will soon be changed. The firing of the boiler is now done by operating a rope or a lever. A fire has rarely to be stirred or nursed in any way except by the adjustment of dampers and rate of feed. The substitution of mechanical and electrical machinery for hand labour naturally led to the substitution of the boiler-house engineer for the aforetime fireman. A competent boiler-house engineer is an indispensable adjunct to the boiler-house staff, and the man who knows his business can easily earn the substantial salary which he can command in this capacity. He, of course, trains his own labourers, but the human element should be, and is being, cut down as far as possible.

Everything possible should be done to obviate wastage of the heat value of coal in the boiler-house before the steam reaches the turbine. Many opportunities for waste, and consequently opportunities for devising ways and means to avoid waste, are still present in the boiler-house. In the present paper the possibilities of further improvement have been indicated as regards space, material, heat, labour, and time; and the sum total of the saving which would accrue even from the partial elimination of present waste under these various heads would represent a considerable proportion of the total charges on revenue in a large electricity supply undertaking. A saving of 1 per cent. in the coal bill of the Glasgow Corporation Electricity Department would this year represent a sum of £2,000.

It is only in recent years that we have come to realise the meaning and the value of a pound better steam consumption in a steam turbine. We now put a money value on steam consumption per $\frac{1}{4}$ th of a pound and stipulate for heavy penalties in the event of failure to comply with guaranteed consumption after allowing a tolerance of $2\frac{1}{2}$ per cent. With an equipment such as has just been described, weekly returns can be prepared giving all the particulars any manager wants to satisfy himself that the plant is being properly handled and is doing its work efficiently. Turbine room data being also available, a weekly sheet showing running statistics may be easily made out.

Recently in the "New York Electrical World" (April 8th, 1916), a short but exceedingly interesting description was given of methods of handling boilers in a 100,000 kw. station. This referred to the boiler plant in the "L" station of the Edison Electric Illuminating Company at South Boston. The editorial referring to the article says: "It is evident in this central station that the electrical end of the establishment has no monopoly of scientific management," and continues that "the liberal use of recording instruments in the steam end of the station and the continuous expert study of operations . . . are all-important factors." The engineer in charge of the boiler-house is expected to maintain the highest efficiency possible with an economical expenditure of time and labour. In this station, containing 48 boilers, they have 36 steam-flow meters, 40 draught gauges, 2 furnace indicators, 1 CO_2 recorder, 2 coal scales, and 1 load indicator. In American stations generally considerably more attention is now being given to boiler-house economy, no doubt due to the increasing price of fuel. The workmen in the boiler-house are educated to interpret the various gauges and recording instruments, and encouraged to take an interest in improving conditions. The instruments are not to be erected and stored away in the chief engineer's room, but are to be in the boiler-room.

Several very fine records of efficiencies have been attained in America. At the Conner Creek plant of the Detroit Edison Company, which has been in operation for a year, they have two 20,000 kw. turbo-alternators, and each turbine is supplied with steam by two large boilers, each boiler containing 23,500 sq. ft. heating surface. The plant is operating at the present time and producing a kilowatt-hour on 1·42lbs. of coal, *i.e.*, a little less than 20,000 B.Th.U. per kilowatt-hour. This shows an efficiency from coal to electrical energy of 17 per cent. The Chicago Commonwealth Edison Company in their Fiske Street station have two turbo-alternators of 20,000 kw. to 25,000 kw. capacity. Over a whole year's run the coal used per unit of output was 1·92lbs., and the average value of the coal as fired was 10,120 B.Th.U. per pound. This gives an average of heating units in the coal as fired per unit of output of 19,450, and also shows a thermal efficiency of some 17 per cent.

PRODUCTION OF CASTINGS IN METAL MOULDS.

THE casting of metals, when accuracy of finished dimensions is requisite, is limited to a certain number of metals with their alloys, and with some of these it is not feasible to have a high head or runner or to force the metal under pressure into the mould, due to the necessity of cleaning the mould from air, steam, or other gases given off from the metal. It is also desirable that all surfaces of the casting should be in firm

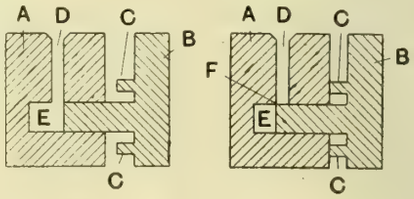


FIG. 1. FIG. 2.

METAL MOULDS FOR CASTINGS.

contact with the mould at the time the metal being cast sets. To effect a casting under these circumstances it has been proposed to use a mould in which a surplus of metal is expelled by a plunger slowly advanced and so arranged that the surplus metal is expelled through a gate, the aperture of which decreases as the plunger advances until finally the plunger cuts off access to the gate and places the metal under pressure.

The accompanying sectional views show a mould designed and patented by Mr. N. C. F. Jensen, 45, Villiers Road, Southall, Middlesex, which is arranged with one or more vertical runners or gates to contain a surplus of metal and constructed so that the plunger can be forced into its final position in the mould against stops which limit its advance and serve accurately to determine the finished dimensions of the casting. The speed of the plunger is not limited, thus reducing the time requisite to make a casting. Fig. 1 shows a mould for producing an article of rectangular section in its dispersed condition, A being one part and B the other; C are the limit stops which determine the approach of A towards B; D is the part through which the metal is poured; E is the part filled by the metal being cast. Fig. 2 shows the mould in its closed or final position, the same letters being used to designate the same parts. It will be seen the approach of the parts towards each other is arrested by the limit stops, and the port at the point F is closed, and the metal in the gate severed from the casting proper.

DISTRIBUTION OF THE RAW MATERIALS IN THE BLASTFURNACE.*

BY GEORGE W. VREELAND.

(*Concluded from page 30.*)

THREE requirements have to be met to secure good distribution: First, proper distribution of the fine and coarse materials in the receiving throat and hopper; second, proper distribution of the materials on the big bell; and third, proper distribution of the materials in the furnace. The first is the keynote of good distribution and presents the greatest difficulties at the present time. With the use of manual labour on the furnace top, good distribution is easily obtained. In hand filling, the buggies always go to the top in the same sequence. As the top of the furnace is always divided off into an even number of spaces (generally six), each charge can be easily rotated with reference to the charge below by simply advancing the ore buggy one space in the circumference of the hopper. By this method any irregularities, such as dumping an extra buggy, or the ore overlapping on dumping the last two buggies of an 8-buggy charge, are taken care of after six rounds or charges are lowered into the furnace.

So far as the distribution of raw materials is concerned, hand filling has always been considered very nearly perfect. But to obtain large tonnage output a radical change had to be made, and the high labour cost in hand filling warrants a heavy investment in equipment. The mechanically filled furnace was the natural sequence. The early skip-filled furnaces were built without much thought to distribution. The life of the lining was consequently very short and the campaign very troublesome. In many cases the skips were simply placed on old furnaces that had done good work with hand filling. This usually developed a poor working furnace and the skip filling was blamed. Operators and engineers attacked the problem, with the result that various designs of furnace tops were brought out.

One of the earliest designs to prevent bad distribution was the Brown rotating top. In this an attempt was made to follow the hand-filling method as closely as possible. This top, as shown in Fig. 1, has a spout C, with gas seal B in the form of a flap door at the lower end to prevent the escape of the gas when the bell is lowered. The door is operated by the flow of material to the big bell. The receiving hopper A and spout C rest on ball bearings and are rotated together, either by the operation of the skip car or independently, a predetermined number of degrees, slightly less than 90°. By this method a series of piles are placed around the big bell, each pile representing a skip load.

One of the objections to this top is the location and form of the material deposited on the large bell, depending on the position of the spout relative to the skip. If the spout is pointing directly opposite the skip incline, the speed of the ore leaving the skip and down the spout will throw the ore considerably further away from the centre of the bell than when the spout is pointing directly under the skip. With the spout in the last-named position, a direct reversal of the flow of the ore must take place, with consequently reduced speed, and in an intermediate position we will have the fault varying between these two extremes. Various methods have been tried to overcome this fault, but none has worked out satisfactorily. Although this top approaches the hand-filling method, this fundamental trouble has not been removed.

The straight double-bell top consists of a receiving hopper into which the skip or skips dump (depending on whether the furnace has a single or a double skip), and a barrel, either straight or slightly tapered, with a small bell fitting it at the lower end. Under the small bell is the large bell closing the top of the furnace. These are the fundamentals of a straight double-bell top; but there are many points that must be kept in view in designing a top of this description, as they all have considerable influence on the final distribution desired. These points are: First, the size and shape of the skip car; second, speed of dumping; third, angle of dumping; fourth, facilities for regulating the dumping position, and maintaining it at an exact point after this has been determined, even with varying loads and ore conditions; fifth, shape of receiving hoppers; sixth, dumping close to the centre line on both axes, so that the lumps and fines will not segregate to separate points in the barrel; and, seventh, the barrel should be of such diameter (not exceeding 5ft. as a maximum) and of such a length as to hold one full skip of coke.

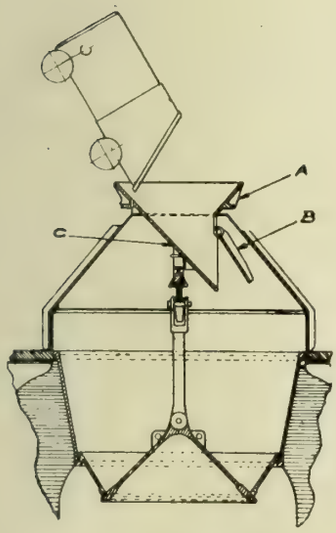


FIG. 1.—THE BROWN ROTATING TOP.

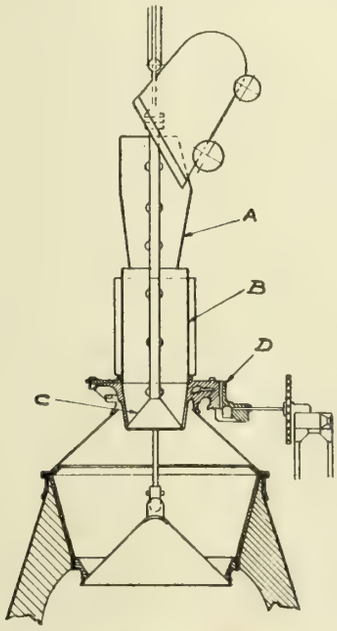


FIG. 2.—THE MCKEE ROTATING TOP.

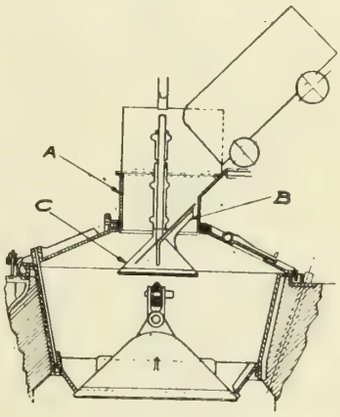


FIG. 3.—THE BAKER-NEUMAN ROTATING TOP.

With these points in view, a top can be built that will do good work; but, as a general proposition, the most successful straight double-bell tops, of which we have numerous examples in this country, are the result of continual alterations and changes over a number of years. The weak points are noted and eliminated as the opportunity affords, until the materials are distributed correctly on the bell. Local conditions will not permit such change in many cases without radical alterations, and often the installation of a rotating top will straighten out a bad distribution and correct errors that cannot be corrected in any other way without complete rebuilding of the top of the furnace and the skip incline.

The McKee revolving top, shown in Fig. 2, is a well-designed straight double-bell top, with the additional feature that the barrel is not connected to the receiving hopper, but,

* Abstract of paper presented at the New York meeting of the American Iron and Steel Institute, May, 1916.

with the small bell, rests on ball bearings and is revolved by a train of gears direct connected to a motor or by cable to a drum with a motor at the bottom of the furnace. The small bell and barrel are revolved around the centre line of the furnace, so that any errors of distribution on the small bell can be spread and equalised over the entire circumference. The method of operating the top varies considerably. Some operators revolve each skip load of a 6-skip charge through an angle of 60° with reference to the load immediately preceding. Others deposit a complete charge on the bell from the hopper in its original position and then revolve the top through an angle of 60 before dumping the materials of the succeeding charge. In either case the cycle is completed in six successive movements of the top. With the highly-developed automatic electric control, the rotation of the top in either of the desired cycles is taken out of the skip operator's hand, being operated in connection with the skip. Thus the top must be revolved in the predetermined cycle if the skip is operated.

The Baker-Neuman revolving top shown in Fig. 3 consists of a revolving hopper A, with a small bell C, on which is attached deflecting plate B. The small bell, with the deflecting plate, is revolved 87° and 30 minutes as the bell is raised. This rotation is accomplished by means of a rifle-barrel arrangement at the upper part of the small bell rod.

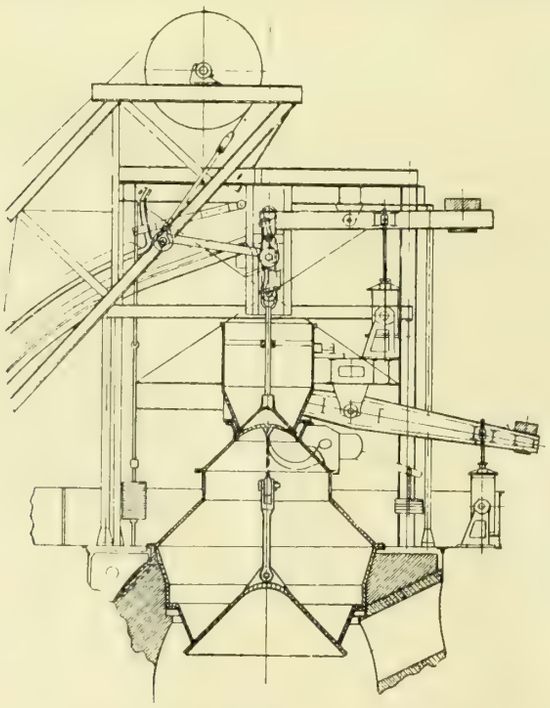


FIG. 4. NEELAND STATIONARY TOP, SINGLE BUCKET HOIST.

The skip load is dumped on the large bell with the deflecting plate and bell in the lowered position, the principal function of the small bell being to act as a gas seal when the large bell is lowered. This top has a tendency to put the raw stock in piles, but not as distinctively as the Brown top.

The Kennedy top resembles the McKee top in many particulars, and is rotated by a cylinder on top or by means of ropes attached to driving mechanism at the bottom.

I have left the discussion of the Neeland top until the last because, although it was one of the first tops designed for the mechanical filling of a blastfurnace, I regard it as a most excellent filling system. The four original furnaces at Duquesne were for several years the only furnaces in this country equipped with this system. About 10 years ago the good qualities of this top began to be appreciated and a number of furnaces have since been so equipped, many of them varying somewhat from the original, but not in principle. The improvements have been due to modern conditions, as it must be remembered that this top is 20 years old.

The Neeland system, illustrated in Fig. 4, consists of a cylindrical bucket with a bell in the bottom to which there is attached a stem by means of which the bucket is carried to the top of the furnace and placed on the gas seal. The material in the bucket is deposited on the big bell by lowering the bell in the bottom. After the bucket is emptied the bell is drawn up and then taken down the incline and deposited on the scale car, or placed on a turntable, or held at the bottom permanently attached to the trolley by means of a swivel.

It was noticed at Duquesne that as the ore flowed from the chutes into the bucket there was an unequal distribution of the lumps and fines, which resulted in the cutting of the furnace lining at some point. To remedy this, the scale cars were equipped with revolving tables on which the buckets were set and revolved continuously while the ore is flowing, or revolved a certain number of degrees after the bucket is full. By thus revolving the bucket the lumps and fines are uniformly distributed, as has been shown by many tests.

A further modification of the original scheme is to discharge the charge from the larry car into the bucket as it hangs on the trolley and then rotate the bucket a certain number of degrees. The rotation is accomplished by means of a rack attached to a hydraulic cylinder meshing into a pinion in the stem of the bucket before the bucket goes to the top. The great advantage of this system is that all the mechanical and electrical devices used to revolve the charge are located at the bottom of the furnace, away from the heat and dust, and are continually under the eye of the operator.

The selection and design of the tops must be left to the furnace management, and they must be governed by the local conditions, with the two main requirements kept in view: First, as nearly perfect distribution of the lumps and fines around the big bell as it is possible to obtain (and it is not so important that this equal distribution should obtain with every charge as it is that it shall be attained over a certain number of charges); and second, that continuous operation of the device is essential. No charging apparatus should be installed that will cause numerous and costly delays for repairs and adjustment.

A rotating top is a most desirable refinement, but it is not a cure for all the "ills and ails" to which a blastfurnace is subject. It will go far, however, toward ironing out and smoothing over some of the troubles of poor distribution, and leave the operator's mind comparatively free to take up other pressing questions which may confront him.

After the small bell has been lowered and the contents deposited on the large bell, no change in circumferential distribution can take place; but the question presents itself as to the quantity of the various materials and the disposition of them vertically on the large bell, also the cycle of lowering the charge into the furnace. There also enters the problem of what might be termed as radial distribution.

With all the mechanical improvements in the methods of charging, and better preparation and selection of the raw materials, too much importance cannot be given to the question of the actual manner of preparing the charge before it goes into the furnace and to its delivery into the furnace proper. The last charge of 14,000lbs. to 16,000lbs. of coke and 30,000lbs. to 35,000lbs. of ore, with the corresponding amount of stone, forms thick, heavy layers of each material; and although the coke does not offer much resistance to the gas, the heavy layers of ore, especially that part thrown towards the centre of the furnace, prevent the free ascent of the gases. The gases in their ascent, following the path of least resistance, cause imperfect and incomplete reduction of the ores. This condition can be overcome only by direct carbon reduction in the lower part of the furnace.

To remedy this, the charge is often split in two, thereby cutting the layers in half, which gives us a ring of ore of maximum thickness near the walls, tapering off gradually towards the centre, where the lumps have a tendency to roll. This method has been demonstrated to be an improvement over the large charge, but a condition may arise wherein we have too much ore close to the walls, and too much coke towards the centre. This would cause the centre to travel too fast with respect to the materials close to the walls and result in greater loss in flue dust.

This system of charging was effected by filling and operat-

ing the bell as follows, assuming, for illustration, a 15,000lbs. coke charge:

7,500lbs. coke on large bell—dump same into furnace.
Half stone and half ore on large bell—dump same into furnace.
7,500lbs. coke on large bell—dump same into furnace.
Half stone and half ore on large bell—dump same into furnace.

The first section gives us a thin layer of coke practically uniform in thickness over the entire area of the furnace, with the ore and stone intimately mixed and deposited close to the walls, some of the lumps rolling towards the centre. In the second section, the coke is placed on the large bell and the ore and stone intimately mixed on top of it; and, upon

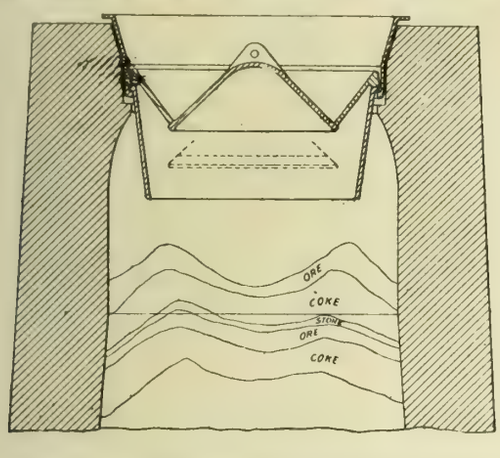


FIG. 5.—KILLEEN STATIONARY DISTRIBUTOR, SHOWING THE MANNER IN WHICH THE MATERIALS ARE DEPOSITED.

lowering the bell to deposit the charge, it is observed that only a small part of the coke leaves the bell before the ore and stone begin to break through and mix with the coke falling from the large bell into the furnace. As this section lies in the furnace, it is found that we have a very thorough mixture of ore, coke, and stone throughout the entire layer.

That this method of filling and distribution in the furnace is satisfactory is proved by the work of one of our furnaces for the year 1915:—

Average tonnage per day, includes blow-in, tons.....	534·4
Average coke per ton of pig iron, includes blow-in, tons	1,994
Average loss, includes blow-in, per cent.....	2·29
Blast temperature, degrees Fah.	891

The blast temperature of 891° Fah. is particularly noticeable, it being all the stoves will produce; and when we compare this furnace with other furnaces working similar raw materials with stoves capable of giving an average temperature of 1,200° Fah., we must give some credit to the filling method described.

A proof that this method of charging is conducive to good results is this: On changing to the thick coke and ore layer, we were unable with the same burden to maintain our hearth temperatures with the heat at our command; and not even in the face of a 10 per cent. reduction in the ore burden did the temperature return. On changing the filling back to the other method, the furnace returned to its normal condition as soon as the charge reached the tuyeres. This was done on two separate occasions with the same results.

Many methods of placing the materials on the large bell and depositing them in the furnace are now in use, and I have experimented with a large number of them; but the methods described above have given very satisfactory results over a long period of time and may prove of value to other operators under similar conditions, especially where a large percentage of fine ores are used.

The almost universal use of the large bell, without distributors of any kind, has standardised its dimensions for furnaces of various stock lines and those using lake ores. After a careful examination of a large number of furnaces, it was found that the diameter of the bell is generally 4ft. less than the diameter of the furnace stock line, although there are a few cases where this difference in diameter is somewhat less, but the above seems to be the accepted figure on large furnaces with 15ft. to 17ft. stock lines.

The angle of the bell in many cases has been increased from 45°, the standard for many years, to as high as 53°. The entire surface is now machined. This has been done in order that the wet and sticky ores will clear the bell and spread in a uniform stratum over its entire circumference. If the ore leaves the bell in an uneven stream after the lowering of the bell is started, it will cause the bell to swing, and the materials still to leave the bell will disturb the distribution and the lay of the raw materials in the furnace.

The Killeen stationary distributor consists of a tapered cast-steel ring, about 6ft. 6in. long and 11ft. to 11ft. 6in. diam. at the smaller or lower end. The large bell is reduced to about 9ft. 6in. diam. These dimensions apply to furnaces with a top 16ft. to 17ft. diam. The material leaves the large bell, strikes the distributor, and is deposited in a ring, as illustrated in Fig. 5. This gives a ring with the maximum fines, the apex of which is about 3ft. away from the wall, the coarser materials rolling to the centre and wall.

The idea in designing this distributing ring was to throw the coarser materials closer to the walls, permitting an easier passage of the gases, and thereby obtaining cleaner walls. During the time of the lower percentage of fine ores and higher percentage of coarser ores, this ring produced results that compared very favourably with those obtained on furnaces using the large bell and no ring. As the lake ores increased in fines, however, furnaces equipped with the Killeen distributor experienced more and more trouble with high pressures and irregular movement of the stock, with resultant high coke and low tonnages. It was readily seen that though our walls were kept comparatively clean we were unable to force the air and gases through the heavy mass of iron-bearing material so far away from the tuyeres. The physical conditions of the ores finally reached that point where it was almost impossible to keep the furnace moving, and it was necessary to go to the large bell.

Below is a comparative statement showing the results obtained on a furnace with a Killeen distributor ring and the

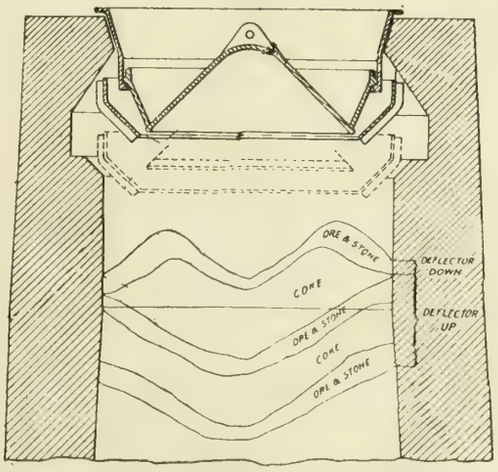


FIG. 6.—MOVABLE MCDONALD DISTRIBUTING RING, SHOWING THE MANNER IN WHICH THE MATERIALS ARE DEPOSITED.

same furnace without the distributor, but with a 12ft. bell, the figures being for 11 months' operation in both cases:—

	Tons per day	Pounds Coke per ton iron.
With Killeen distributor	497·7 ...	2,240
Without Killeen distributor ...	531·1 ...	2,029

This type of ring served one good purpose in that it protected the stock line of the furnace, but operating conditions were such that we could not afford to pay the price for this protection.

The McDonald distributor, shown in Fig. 6, differs from the Killeen in that the large bell is of standard diameter, the same as would be used without the distributor, and the distributing ring is raised or lowered as desired. The usual method of operating this type of top is to keep the distributor in the upper position clear of any material as it leaves the bell for three or more charges. The distributor is then lowered and the succeeding charge is dropped into the furnace. Having a movable distributor, the operator can throw

the fines toward the wall from the large bell, the distributor being in the upper position and out of the path of the raw material; or, by lowering the distributor, the operator can throw the major portion of the coke to the centre of the furnace, with the fines and excess of ore away from the wall.

One of the latest developments in distributing rings below the large bell is the one designed by E. E. Slick, and shown in Fig. 7. This distributing ring is permanently set in the furnace top and combines some of the features of the Killeen and McDonald rings, with the further and radical development that the lower portion of the ring consists of a number of fingers equally spaced, with the lower end projecting inwardly.

As the material leaves the large bell, those portions which impinge upon the fingers are deflected toward the centre of the furnace, the portions which pass between the fingers continue in their travel outwardly towards the walls of the furnace, and that which impinges against the upper portion of the straight ring or skirt drops more or less vertically. In this way the charge is deposited in the furnace so as to form a number of vertical columns. These columns of finer stock are formed by the separation of the coarser portions

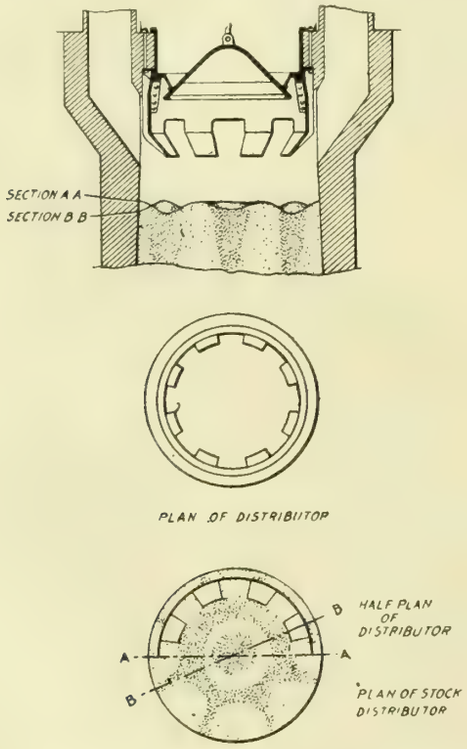


FIG. 7.—SLICK DISTRIBUTOR, SHOWING WHAT IT ACCOMPLISHES.

of the charge which roll down from each of the small mounds formed on the surface at the stock line.

This design permits of a relatively uniform ascent of the gas, due to the lines of greater porosity surrounding the denser columns of fine materials, and also tends to give a more intimate mixture of the raw materials over the entire area with a certain percentage of fines close to the walls, which condition we have found is so necessary for our operation. The use of the Slick distributing ring has shown some meritorious results. As such excellent work is being done on furnaces without a distributing device below the large bell, its necessity is not apparent, at least under our present conditions.

So much for the technical and present-day aspect of this problem of distribution, the importance of which will not be under-estimated by any furnace operator. Smooth operation, quality of product, minimum labour cost, low fuel consumption, high yield, and large tonnages are all matters of prime importance to-day. But no paper on this subject would be complete that did not at least touch on that great economic problem wherein the practice of to-day has its direct bearing on the problems of to-morrow. I refer to the conservation of our natural resources, and particularly to the conservation of those raw materials connected with the iron and steel industry.

Nature has bountifully endowed us. The largest and richest coal and ore deposits have been given into our keeping for our own use in this generation and as trustee for future generations. If we are to discharge that obligation conscientiously, we should see to it that in this, our generation, all metallurgical processes and operations shall be so conducted that waste and loss in raw materials are reduced to that point which, based on our ability, is the lowest practical limit.

The estimated amount of iron ore to be brought down from the Lake Superior region this year reaches the enormous figure of 66,000,000 gross tons, practically all of which is to be used for the production of pig iron. If by more perfect distribution of our raw materials in the blastfurnace and with other improvements that could be effected in many furnaces, a saving of only one-half of 1 per cent. of the metallic yield should be effected over this entire quantity of lake ore, it would mean that 610,000 tons of iron ore could therefore be reserved annually for future consumption. Since the more perfect distribution reduces our metallic loss, so does it reduce the coke consumption, as they go hand in hand; and if we could reduce our coke consumption for the smelting of this quantity of ore by 5 per cent., we would save 1,750,000 tons of coke, with 2,500,000 tons of coal left in the mines for future generations to use.

The thought of effecting a saving of one-half of 1 per cent. in yield and 100lbs. of coke per ton seems small when we talk of them in our every-day practice, but in the aggregate they amount to large figures.

DETERMINING GRAIN SIZE IN METALS.*

BY ZAY JEFFRIES, A. H. KLINE, AND E. B. ZIMMER.

IT is well known that many properties of metals vary with the size of grain or cell. For most industrial purposes, where a high ultimate strength and a high elastic limit are desired, the manufacturer tries to produce a fine-grained structure. For some purposes, as in transformer iron, a coarse-grained structure is desirable. The terms "fine grained" and "coarse grained" are used only in a relative sense. For example, fine-grained cast copper might have grains 100 times larger than coarse-grained high-speed steel. Similarly, a fine-grained steel rail might have grains or cells 100 times larger than coarse-grained wire made of steel from the same heat. In some metals the change in grain size is more appreciable than the changes in any of the properties determined by the tensile test. Furthermore, in metals which have been annealed or subjected to high temperatures, grain size may prove a better indication of the life of the metal in use than the tensile test. One of the authors was able to supplant the tensile test with grain-size determinations in the control of metal for a specific use, the latter determination being more indicative of the life of the metal than the tensile test. A grain-size determination with a tensile test is, of course, more valuable than either test singly.

At present a decided dearth of data exists as to actual grain-size determinations in metals, there being consequently a corresponding lack of ability to interpret the determinations after they are made. It would be desirable to have correlation made between grain size and properties of metals, comparing thousands of determinations. In this way, grain-size determinations might be interpreted in much the same manner that a tensile test is now utilised. One of the chief reasons that more grain-size measurements have not been made is the excessive work involved in making a determination. The planimeter method is accurate, in fact, too accurate for the nature of the work involved, but it is slow and tedious. It involves the tracing of the outside boundary lines of a group of grains, counting the grains, measuring the area with a planimeter and a calculation which is different for each determination. Furthermore, the method requires a planimeter, which piece of apparatus might not be available in all metallographic laboratories.

The authors have developed a method by means of which a grain-size determination can be made in one-fifth the time required by the planimeter method. The method is as accu-

* Abstract of paper presented at the February, 1916, meeting of the American Institute of Mining Engineers.

rate as the sampling of the specimen and requires no apparatus which is not available in metallographic laboratories.

The planimeter method may be used in either of two ways. The image of the metal specimen may be projected on a piece of paper and the grain boundaries traced, as shown in Fig. 1. The total area divided by the number of grains enclosed will give the average area per grain. The second method, which involves less time, is to trace on the paper just the outside lines bounding the area of a group of whole grains. The number of included grains is then indicated by check marks on the paper, as shown in Fig. 2. Since the counting of the grains can be done at the time of checking, this way is the shorter. The following example is taken from an actual determination. The area which was determined by measuring with a planimeter was 5·92 sq. in. The number of grains enclosed was 61. Therefore the average area per grain was $\frac{5\cdot92}{61} = 0\cdot09705$ sq. in. The observation was made at a magnification of 100 diameters. Then $\frac{0\cdot09705}{100 \times 100} = 0\cdot000009705$ sq. in., which was the actual area per grain. $\frac{1}{0\cdot000009705} = 103{,}040$ grains per square inch.

The Heyn method depends for its accuracy on the assumption that the intercepts of a straight line intersecting a number of grains will be proportional to the square roots of the areas of the grains. In other words, the square of the average intercept will be the average area per grain. Heyn applies this assumption as shown in Fig. 3. The number of grains is counted along a line, such as AB. The first incomplete grain is counted as one, and the last grain is not counted. By taking a number of lines parallel to AB and counting the grains intersected by each, the average intercept in one direction is obtained. The average intercept in the direction CD, at right angles to AB, is obtained in a similar way. The product of the two average intercepts is the average area per grain. For example, suppose the number of intercepts in the direction AB is 79 and the distance 20in. The average intercept is $\frac{20}{79} = 0\cdot2533$in. Likewise, suppose the number of intercepts counted in the direction CD is 72 and the distance is 16in. The average intercept in this direction is $\frac{16}{72} = 0\cdot222$in. Then the average area per grain is $0\cdot222 \times 0\cdot2533 = 0\cdot05623$ sq. in. If the magnification is 100 diameters, then $\frac{0\cdot05623}{100 \times 100} = 0\cdot000005623$ sq. in., actual area per grain, or $\frac{1}{0\cdot000005623}$ = grains per square inch.

It is not necessary to trace the grain boundaries to apply Heyn's method. A piece of cross-section paper may be used for a screen and the grains intersecting each line counted and the distance measured.

The intercept method is based on the same assumption as Heyn's method, but the readings are not confined to series of parallel lines. The method of procedure for determining the grain size by the intercept method is as follows: In Fig. 4, the line AB is drawn through the centre of the field. This line intersects 13 grains in a length of 2·58in. The average intercept per grain is therefore $\frac{2\cdot58}{13} = 0\cdot198$in. $(0\cdot198) = 0\cdot0392$ sq. in., the average area per grain. If we consider the magnification as 100 diameters, then $\frac{0\cdot0392}{100 \times 100}$ $0\cdot00000392$ sq. in., the actual area per grain. The number of grains per square inch is $\frac{1}{0\cdot00000392} = 255{,}000$. In order to get the average diameter per grain, sufficient lines should be taken to intersect from 50 to 500 grains. In actual practice, this method is shortened considerably. An eyepiece with a graduated scale may be used in place of the regular eyepiece. The length of an even number of grains can be measured direct and the approximate grain size obtained in a short time.

The method used by the authors has for its object the quick determination of the equivalent number of whole grains included within a circular portion of an image. It is evident that some of the grains will be completely included within the circle, and that some will be intersected by the circumference of the circle. The former will have no correction factor. The boundary grains, however, will be partly inside and partly outside the circle. In Fig. 5, the grains marked with a check mark are completely enclosed and those marked + are the boundary grains. The average portion of each boundary grain included within the circle may be found as follows: The grains completely included within the circle are first counted and checked. Then, the boundary grains are checked with a different mark and counted. (If the counting is done at the time of checking, the time of making a determination will be shortened.) In Fig. 5 there are 37 included grains and 22 boundary grains. The area of the included grain by planimeter is 1·9 sq. in. The area of the circle whose diameter is 1·83in. is 2·635 sq. in. $1\cdot9 : 2\cdot635 = 37 : X$. $X = 51\cdot3$, the equivalent number of whole grains within the circle. $51\cdot3 - 37 = 14\cdot3$, the equivalent number of those grains in the inside portions of the 22 boundary grains. $\frac{14\cdot3}{22} = 0\cdot65$ average portion of each boundary grain within the circle.

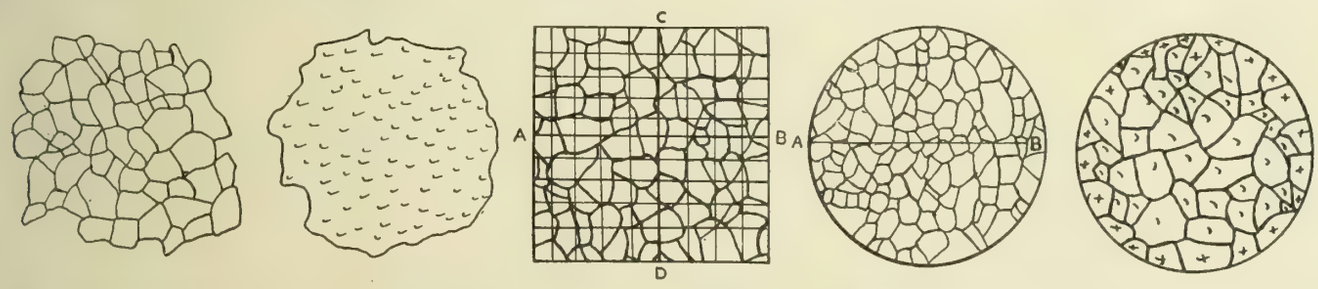


FIG. 1—PLANIMETER METHOD FIG. 2—PLANIMETER METHOD. MODIFIED FIG. 3—HEYN METHOD FIG. 4—INTERCEPT METHOD FIG. 5—AUTHORS' METHOD

If this factor be determined on a large number of samples, it may be used on unknown samples to find the equivalent number of whole grains within a circular area. If we call this factor y the total number of grains within a circle is $z + yw$, where z is the number of grains completely enclosed and w is the number of boundary grains. The factor y has been determined empirically on 175 samples. The results are given in the following table, the first column representing the number of grains completely included within the circle:

Grains completely included.	Average value of y.	Number of determinations.
10-20	0·556	11
20-30	0·582	15
30-40	0·542	13
40-50	0·574	10
50-60	0·590	11
60-70	0·600	12
80-90	0·577	11
70-80	0·576	10
90-100	0·596	10
100-120	0·551	11
120-140	0·618	11
140-160	0·546	10
160-180	0·566	10
180-200	0·558	11
200-230	0·606	10
230-290	0·622	9

The average value of the factor y, for 175 determinations, is 0·581. The same factor can be used for all numbers of grains included within the observed area, but it is recom-

mended that all important determinations have at least 50 grains included within the circle. Since 0·581 is nearer to 0·6 than to 0·5, we have adopted 0·6 as a general factor for all determinations. It should be noted that an error of 1 per cent. in the determination of the whole-grained equivalent of the boundary grains makes an error of less than 0·25 per cent. in the final result, since more than 75 per cent. of the total area of the circle is occupied by the included grains. The following is an example of how the factor is used:—

Enclosed grains	66·0
Boundary grains	28·0
Factor	0·6

$66 + 0{\cdot}6 \times 28 = 82{\cdot}8$ grains within the circle.

From the magnification the number of grains per unit of area can be readily calculated. A way to make a grain-size determination by the authors' method has been developed. A circle 79·8 mm. diam. is used. In the following table is given the factor, for each magnification, by which the equivalent number of whole grains within the circle is to be multiplied to obtain the number of grains per square millimetre.

Magnification used.	Diameter of circles, millimetres.	Factor.
25	79·8	1
50	79·8	1
100	79·8	2
150	79·8	2·000
200	79·8	4·500
250	79·8	80·000
500	79·8	12·500
750	79·8	5·000
1,000	79·8	112·500
1,500	79·8	2·000
2,000	79·8	4·500
		8·000

The following example shows how this table is used: Included grains, 61; boundary grains, 35; magnification, 100. Grains per square millimetre $= (61 + 0{\cdot}6 \times 35)2 = 164$. Similar tables can be made for square-inch calculations, or for circles of different diameters.

A comparison of the methods described indicate that the intercept method and Heyn's method are not accurate. The largest error found in 187 determinations by the authors' method was 6·4 per cent., the average error 2·1 per cent., and the average algebraic deviation from the planimeter measurements, plus 0·25 per cent. An average of 30 representative determinations showed that 78·5 per cent. of the total area of the circle was occupied by the included grains. This portion is determined accurately by the authors' method. The factor is used in determining only 21·5 per cent. of the number of grains. An error of 5 per cent. in estimating the boundary-grain portion makes an error of slightly over 1 per cent. in the final result. A square or any other shape might be used, instead of a circle. It seems probable, if a square or rectangle were used, that the factor would be 0·5 instead of 0·6, when the circle is used.

Some metallographic specimens have more than 5,000,000 grains exposed on one face. It becomes necessary to obtain a representative sample of this face. The authors have tentatively adopted these general rules, which, of course, can be changed as occasion demands:—

Use such a magnification that about 50 grains will be included within the circle. It is better to have more than 50 grains included within the circle than less, but it is always recommended that an even number of magnifications be used, even though the number of included grains should exceed 100.

Make at least five determinations at about equal intervals along the diameter of the specimen. The average of all of the determinations is taken as the final result. It is evident that if there is much difference in grain size between the edge and centre of the specimen, the former should have the greater weight.

If the samples are small enough, for example, small wire, it is advisable to determine the total number of grains on transverse sections, and the total number for a given length on longitudinal sections. It is sometimes practical to do this with larger, coarse-grained specimens, either microscopically or at low magnifications.

When one part of a specimen differs greatly from another part in grain size, do not average the separate determinations, but record each and note the position of each determination by means of a freehand sketch.

In samples which have been cold worked, the relative degree of cold work in any direction is expressed by the ratio of the length divided by the width of the grains. For obtaining this ratio it is recommended that Heyn's method be used.

OFFICIAL MAXIMUM PRICES FOR COKE, IRON, AND STEEL.

THE Minister of Munitions gives notice, under date July 7th, that he hereby permits all persons until further notice (*a*) to buy, sell, or deal in; or (*b*) offer or invite an offer or propose to buy, sell, or deal in; or (*c*) enter into negotiations for the sale or purchase of or other dealing in certain war materials, subject to the following conditions: (1) This permit shall not affect the provisions of Regulation 30 (B) of the Defence of the Realm (Consolidation) Regulations. (2) No sale or purchase of material in the United Kingdom not being under a contract in writing entered into prior to the date of this notice shall be at a price exceeding the prices specified in the Schedule hereto with reference to the respective classes and descriptions of material therein referred to, provided that this condition shall not apply (1) to a sale or purchase under a special permit granted by the Minister of Munitions, or (2) to a sale or purchase which is not a transaction or one of a series of transactions involving the sale or purchase of more than 5 tons, or (3) to any sale by a manufacturer of finished steel rolled from steel purchased by him, or (4) to a sale or purchase of material the export of which has been duly sanctioned. (3) Upon any such sale or purchase the seller and purchaser shall comply with any directions, whether of general application or otherwise, which may from time to time or at any time be given by the Minister of Munitions with regard to the use or disposal of the said war material. The Schedule referred to is as follows:—

Maximum Prices.	Per ton net. f.o.t., Makers' ovens. £	s.	d.
Durham and Northumberland:			
Blastfurnace coke	1	8	0
Foundry coke	1	10	6
Lancashire: Blastfurnace coke	1	5	8
Midland Counties: Blastfurnace coke	1	5	8
South Wales and Monmouthshire: Blastfurnace coke	1	10	0
West Yorkshire: Blastfurnace coke	1	5	8

	Per ton net. f.o.t., Makers' works. £	s.	d.
Hematite Pig Iron—East Coast:			
Mixed, Numbers 1, 2, and 3	6	2	6
Special quality, containing under 0·04 of phosphorus and sulphur	6	7	6
Special quality, containing under 0·03 of phosphorus and sulphur	6	15	6
Special quality, containing under 0·02 of phosphorus and sulphur	7	0	0
Hematite Pig Iron—Scottish:			
Mixed, Numbers 1, 2, and 3	6	2	6
Special quality, containing under 0·03 of phosphorus and sulphur	6	15	6
Special quality, containing under 0·02 of phosphorus and sulphur	7	0	0
Hematite Pig Iron—Welsh:			
Mixed, Numbers 1, 2, and 3	6	2	6
Special quality, containing under 0·03 of phosphorus and sulphur	6	15	6
Special quality, containing under 0·02 of phosphorus and sulphur	7	0	0
Hematite Pig Iron—West Coast:			
Mixed, Numbers 1, 2, and 3	6	7	6
Special quality, containing under 0·03 of phosphorus and sulphur	6	15	6
Special quality, containing under 0·02 of phosphorus and sulphur	7	0	0
Cleveland Pig Iron:			
Number 1	4	11	6
Other grades	4	7	6

	£	s.	d.
Derbyshire, Leicestershire and Nottinghamshire Pig Iron:			
Forge	4	5	0
Foundry numbers	4	7	6
Lincolnshire Pig Iron:			
Basic or foundry	4	7	6
Northamptonshire Pig Iron:			
Forge	4	2	6
Foundry numbers	4	5	0
North Staffordshire Pig Iron:			
Forge	4	10	0
Foundry	4	12	6
Basic	4	15	0
South Staffordshire, Shropshire, and Worcestershire Pig Iron:			
"Part mine" forge	4	10	0
"Part mine" foundry	4	12	6
Common Staffordshire	4	5	0
"All mine" forge	5	10	0
"All mine" foundry	5	15	0
"Warm air" forge	7	0	0
"Warm air" foundry	7	10	0
Special quality Lord Dudley's silicon	7	17	6
Cold blast iron	8	17	6
Scottish Foundry and Forge Pig Iron:			
Nos. 3, 4, and lower grades of Monkland, Dalmellington, Eglinton, and Govan	5	14	0
Nos. 3, 4, and lower grades of all other brands	5	15	6
No. 1 quality (Scottish) to be 5s. per ton above these prices.			

To the above-mentioned prices for pig iron a sum not exceeding 1¼ per cent. on such prices may be added in the case of sales by persons other than the makers.

Maximum Basis Prices for Steel.

	£	s.	d.
Ship plates, ¼in. and over	11	10	0
Boiler plates	12	10	0
Subject to extras for special thickness, sizes and qualities not exceeding those customary in district of manufacture.			
Angles, ordinary sizes	11	2	6
Joists, ordinary sizes	11	2	6
Rails (railway), over 60lbs. per yard	10	17	6
Sheet and tin-plate bars	10	7	6
Blooms and billets, ordinary mild steel	10	7	6
Blooms and billets, special	11	0	0
Rounds and squares, 3in. to 5½in. diameter or square (untested)	12	10	0

Tees, channels, flats, bulb angles, zeds, and other sections of which the prices are customarily based on the price of angles to be at price of angles, subject to extras not exceeding those published in any list recognised by the trade in the district of manufacture and current on July 7, 1916.

All subject to extras for special sizes and qualities not exceeding those published in any such list as above.

Heavy steel melting scrap ..... £5. 10s. per ton delivered buyers' works.

Turnings and borings ..... £2. 15s. per ton delivered buyers' works.

Maximum Price for Bar Iron.

Standard quality, ordinary sizes and merchants' lengths, £13. 15s. per ton net, f.o.t. makers' works.

Marked bars, £15 per ton less 2½ per cent. f.o.t. makers' works.

Subject to extras for special sizes and qualities not exceeding those published in any such list as above.

To the above mentioned prices for bar iron and steel a sum not exceeding 2½ per cent. on such prices may be added in the case of sales by persons other than the makers.

Maximum Prices for High-speed Tool Steel.

Finished bars, 14 per cent. tungsten ...2s. 10d. per lb. delivered buyers' works.

Finished bars, 18 per cent. tungsten ...3s. 10d. per lb. delivered buyers' works.

(Subject to usual extras for special sizes.)

Scrap:

Millings and turnings, 5d. per lb. net, delivered steel-makers' works.

Bar ends, 6d. per lb. net, delivered steel-makers' works.

All communications with reference to the above order and permit should be made to the Director of Materials, Armament Buildings, Whitehall Place, London, S.W.

SCIENCE AND INDUSTRY.

THE interim report of the Board of Education Consultative Committee on scholarships for higher education, recently issued, contains a number of important recommendations. The report mentions that great German firms study to earn a profit, but in their operations the advance of Germany is also a constant aim. We have hitherto ignored the national motive. A new national spirit has been aroused in our people by the war. If we are to recover and improve our position at the end of the war that national spirit must be maintained, for unless every man and woman comes to know and feel that industry, agriculture, commerce, shipping, and credit are national concerns, and that education is a potent means for the promotion of these objects among others, we shall fail in the great effort of national recuperation. In plainer words, our great firms will not make money, wages will fall, and wage-earners will be out of work. In the task of making good our losses in material, time, and business connections, we must neglect no source of strength. We must approach that task as a national task of vital importance to our well-being and our self-respect as a nation. One need will be to bring the practical man and the man of science to work together for a common end, and to value each other's qualities. We have enough science at the present moment to make such co-operation ten times more productive for the future than it is now, but it is said that our scientific men are not sufficiently practical, while our practical men ignore the scientific method and the potentialities of science. We need that men of science shall be also practical; that men of practice shall be also scientific. A second need will be the improvement of the existing means of scientific and technological instruction and the encouragement of scientific research, especially in the direction of technology. A third need will be to improve the education of the workman, and to secure from all classes of the community, by scholarships and otherwise, a steady supply of able, well-trained, and zealous students to fit themselves for the conduct of scientific business and for the improvement of its methods. Referring to the great burden of debt we shall have to bear after the war, the report recognises that we shall have to practise economy, but declares that to stint education, study, or research will be the worst of all possible forms of economy, and that it is certain unless we are prepared to spend upon education more effort, more thought, and even more money after the war than we did before, we shall not regain or retain our place among the nations. It is not enough for the State to found institutions and provide scholarships; it is necessary that the managers of industry and commerce should come to know the value of scientific training in their advisers. It is necessary that scientific training should be recognised as a highly important qualification for directive posts. Then by degrees it may come to be understood that scientific training is an effective, though not the only, means to advancement. The needs of the nation are the needs of the individual, but it is necessary the individual should understand them and feel them to be his own. Among the recommendations made by the Committee are that the system of scholarships should be judged from the point of view of the training of men and women according to their capacity, that they may serve the needs of the nation in the manner for which they are best fitted, the furtherance of industry, agriculture, and commerce being regarded as a principal need of the nation, and higher education as a means to this end; the extension of scholarships to students from evening classes and work schools to technical colleges and universities; modification of matriculation tests at universities so as to admit to full university privileges selected scholars trained by part-time or discontinuous instruction; an immediate increase of university scholarships to women; an annual grant in aid of £100,000 for strengthening the higher parts of selected secondary schools in order to hasten the extension of higher secondary education; State maintenance grants of £25 a year to 1,500 selected scholars to enable them to continue their secondary education from the age of 16 to 18 or 19; 250 scholarships annually at a cost of £67,500 for secondary

school students to pursue scientific or technical subjects at the universities. Other recommendations are made by the Committee for the extension of university scholarships, the total initial cost of which to the nation is estimated at £329,500.

PARTICULAR USES OF BRONZE IN MOVABLE BRIDGES.*

BY CLEMENT E. CHASE.

For each of the several distinct uses of bronze in bridge work, there is doubtless one composition that best combines entirely satisfactory quality with minimum cost, but conditions vary so, and scientific research into the matter is so meagre, that it is hardly possible to do more than indicate the desirable qualities and name some compositions which have proved satisfactory in service. Further, most of these uses of bronze are not really severe tests of bearing metals, in that the loads usually are determined by other considerations than the strength of the metal, and that the bearings are not used constantly enough in motion to make endurance to wear or heating difficult problems.

Of the desirable qualities, it is first important that the friction be as little as possible. Theoretically, the harder the bearing metal the better as to friction, and consequently heating will be reduced. However, this presupposes perfect adjustment between bearings and the rotating parts, as otherwise there will be excessive wear and heating at the points of contact. From this has come the conception of the ideal bearing metal as one containing a hard constituent to support the load and a soft constituent to act as a plastic support for the harder grains. In this case the yielding of the soft constituent will remedy the irregularities of bearing.

For some uses the resistance to wear may decide between the various bronzes. Tests in the laboratory and in actual practice have shown that the softer bronzes wear less, and that the bronzes with lead content are superior in this regard to those without, and that this advantage increases with the proportion of lead.

A certain amount of strength in compression, to resist pressure without flowing, is required. Computed unit stresses, however, usually are low, as they commonly are fixed in the case of trunnions or journal bearings by the amount that will allow the maintenance of an oil film between rotating part and bearing. When used in gears or worms, the strength to resist tension is an important quality. The hardness of the bearing must be regulated to that of the rotating parts, lest the latter suffer from abrasion.

The bronze should be as free from brittleness as compatible with its other qualities, as it may be exposed to shock both before and after being placed in use. It is a common experience for a bronze bushing made to meet the requirement of 24,000lbs. or 27,000lbs. minimum elastic limit to crack in machining or handling. There is also the risk of this happening after the bearing is in use. C. H. Mercer, chief engineer of the Pennsylvania Steel Company, writes: "We have had no reports of breakage due to material being too soft, but have had one report of the bearing breaking on account of being too hard. A sample was taken from the broken piece and it developed 21 per cent. tin."

Uniformity of structure and freedom from oxides are necessary features of good bronzes. Fineness of microstructure is important in that this is found to accompany high physical properties and will have an important effect on the wear of both the bearing and the rotating part. Considering the agency of wear as the dislodging of the hard particles from the soft matrix, it is seen to be an advantage that these particles be as small as possible. Some day, it is hoped, microscopic examination for structure may be required for important bearings. These are the four following distinct classes of duty for bronze in connection with movable bridges:—

(1) For centre-bearing discs or drawspans, working between surfaces of hardened steel at low speed and under heavy pressures of from 3,000lbs. to 3,500lbs. per square inch. When used in this way there is a chance of poor lubrication due to the oil film being squeezed out during the periods of rest. To reduce the friction of turning and meet the unit pressures, a hard bronze is necessary. Wear will not be an item of importance, as the number of revolutions during the lifetime of a bridge would never cause appreciable wear. Centre-bearing discs are commonly used against hardened, or at least high-carbon, steel surfaces, so that the hardness of the bronze usually need not be limited by fear of abrasion. The lenticular shape of the discs and the manner in which the load is applied make the risk from brittleness a minimum. The use of phosphorus in the bronze will aid in securing both hardness and freedom from oxides.

An extremely hard bronze usually is specified, the requirement for elastic limit in compression being a minimum of 24,000lbs. or 27,000lbs. per square inch, with a set under 100,000lbs. per square inch of not over $\frac{1}{10}$in. Tool-steel bearing surfaces, often oil-hardened, are commonly used with this bronze. The foundry must make a bronze with tin content about 20 per cent. and phosphorus 0·8 to 1·2 per cent. to meet this specification, which places no limit on hardness. The result is an extremely brittle material that, the bridge shops have learned, must be handled with every precaution. Test results on bronze made to this specification frequently show elastic limits of from 30,000lbs. to 40,000lbs. per square inch in compression. The bearing surfaces are very apt to warp slightly in hardening after being machined, and it then becomes a very difficult matter to secure uniform bearing on the disc. The writer believes that a somewhat softer bronze, with tin content about 16 to 18 per cent. (elastic limit about 20,000lbs. or 24,000lbs. per square inch), working between high-carbon (not hardened) steel bearing surfaces would be found equally satisfactory in service. For working in the shop it would be greatly superior to the harder metal, and a uniform bearing would be comparatively easy to obtain.

(2) For trunnion bearings carrying medium or structural steel trunnions at low speed under moderate computed pressures, usually from 1,500lbs. to 2,000lbs. per square inch. These unit pressures, computed on the projected area of the trunnion, are limited to these amounts by considerations of lubrication. A hard bronze is desirable for two reasons: First, during periods of rest the oil film may well be squeezed out and then a hard bronze is advantageous, as friction will be less and the chance of gripping of the trunnion less. Friction is important, as the power consumed in opening and shutting the bridge will depend largely on it. Second, it is entirely probable that the actual unit pressures in the surface of contact between trunnion and bearing are for a long time, possibly always, considerably in excess of those computed. Wear is not important in this case. Trunnions are commonly of structural grade steel, and B. R. Leffler refers to two cases in which shafts, where a very hard bronze was used, became abraded. The possibility of unevenness of the support of the bushing, its comparative thinness and the chance of shock make the question of brittleness rather important. The breakages in handling in the shop, and during and after erection, usually have occurred in bronzes of this type when made of hard (20 per cent. tin) bronze. While phosphor bronzes of the hard type (copper 80-82 per cent., tin 20-18 per cent.) have been used frequently in trunnion bearings, as also has been the standard lead bronze (copper 80 per cent., tin 10 per cent., lead 10 per cent.), the medium bronze recommended by Mercer and incorporated in Leffler's specifications, seems for many reasons best. The physical qualities can be met with a bronze of about 14 per cent. tin content.

(3) For shaft bearings working under light loads at high speeds. In this case wear is a matter of first importance, as it usually is a matter of great difficulty and expense to replace the bushings of an important bearing in the machinery of a movable bridge. This makes a fairly soft lead bronze desirable. Lubrication usually can be counted on to be continuous, and the pressures hardly are great enough to make it likely that the shaft would be gripped even if the bearing ran dry for a short time. The tin content should be comparatively low, because it then is easier to have the lead uniformly distributed throughout the casting. For uniformity and freedom from oxides which may cause heating, phosphor bronze should be used. The "standard" lead phosphor bronze (copper 80 per cent., tin 10 per cent., lead 10 per cent.) is used commonly and

* From the report of Sub-committee C to the American Railway Engineering Association.

probably is as well adapted as any other to the purpose. Specifications should not call for physical properties incompatible with these proportions.

(4) For gears and worms, requiring resistance to both tension and wear The composition must be hard so as not to flow, but not so hard that the pinion or gear that is engaged will become abraded, nor brittle, as shock is very likely to occur. High tensile strength, ductility, and denseness are prime requisites. A lead bronze is unsuitable, being too soft and uncertain in tension. Probably there is nothing better for this use, where its strength is sufficient, than the venerable gun-metal formula, copper 88 per cent., tin 10 per cent., zinc 2 per cent. This is familiar to most foundries, and splendid sound castings can be obtained. Phosphorus does not seem necessary with the zinc present, and some authorities assert that the bronze is injured by the presence of both.

SOME CAUSES OF RAIL FAILURES.*

BY J. S. UNGER.

RAIL manufacturers have been engaged for years in making studies and investigations looking towards rail improvement, beginning with the manufacture of the steel and through all the subsequent operations to the finished product. In all rails the primary consideration is safety, durability, and cost. The severity of modern railroad service makes it necessary that every effort be made to ensure safety as well as to produce more durable rails. Heavier rails are necessary to meet these severe conditions. The heavier rail is an improvement when it is not merely an added weight of 5lbs. to 10lbs. per yard, which is one-third of that per foot, but a pronounced increase in size. Weight in rails, except as it affects cost, is not objectionable, as it is not a moving load. The impression exists that heavy rails lack ductility. This is true in a comparative sense only. A heavy rail cannot be distorted to the same extent as a light rail. A re-rolled 30-lb. rail will stand more bending than a 100-lb. rail from which it has been rolled, even though the finishing temperatures were the same. This is to be expected, as a similar condition exists when any article of steel is compared with one of heavier section made from the same steel. A piece of wire can be bent more than a 3in. axle, although both may be made of the same steel. There is a growing tendency at the present time on some railroads to install heavier rails. One railroad has installed 135-lb. sections on its fast passenger tracks, and another system has recently placed a large order for 130-lb. rails. Some of the very heavy sections have not proved to be quite as satisfactory as was expected at the beginning of their use, but later experiments with some modifications have given satisfactory results. It would be idle to predict where this increase may end, but a 200-lb. rail is a future probability. A new rail mill at the Edgar Thomson Works, at Bessemer, Pa., was completed early in the present year. This mill is capable of rolling rails up to 150lbs. per yard and will be able to supply any demand for heavier rails for some time.

In looking towards possible rail betterment, the Edgar Thomson plant is using an ingot 23½in. square, instead of the smaller ingot used by many of the older mills. This ingot is bloomed at the beginning in a tandem, 2-high, non-reversing 48in. mill, with two passes in each stand. The ingot first goes through a pass in the first stand, then is turned 90° and given a pass in the second stand. It is then returned to the first stand by a turntable and carrier, again turned 90°, given another pass, turned again and given a last pass in the second stand, thus rolling the ingot on all sides, turning at every pass before being sent to the 3-high 40in. reversing blooming mill, which completes the blooming, The bloom is then sheared, reheated, and rolled on the rail mill.

The advantages of preliminary blooming lie in the large fillets used in the rolls, avoiding any tearing at the corners of the ingots, the very slow rolling speed employed giving a kneading action to the plastic surface of the ingot, and the rolling on all sides, working all surfaces of the metal equally. This mill has been rolling 130-lb. rails for some time. To give an idea of the quality of these heavy rails, not a single rail has failed in any of the mechanical tests made at this works to date. Other features of this mill are noteworthy, among them being the commodious underground passages to the mill machinery and to the soaking pits. This facilitates making changes in the mill equipment when it is necessary. The investigations of the rail manufacturer have not only covered the manufacture of rails, but also some of the causes of rail failures. I do not believe a rail-testing machine can be built which will exactly imitate service conditions. The vibration and loading might be imitated, but to imitate the speed at which they are applied would be difficult, if not impossible. In studying rail failures, a study should be made of some of the causes which may assist in producing them. Bad gauging of track, worn wheel tread and flanges, flat spots on wheels, poor trucks, poor sub-grade, insufficient ballast, improper counterbalance on engine, bad ties, and insufficient area of contact between wheel and rail should be considered. Rail maintenance and the condition of rolling stock exercise an important influence. Rails rarely break on trestles, crane runways, or bridges. When failures occur at these points, they are due to crushing or split heads, which are noticeable and can be removed before an accident occurs. In an accident, a broken rail may show better quality than the adjoining or opposite rails which did not break.

The question might be asked here: When is a rail a good rail? Rail failures are few when compared with the number of rails used annually, and would not be considered serious in most of the ordinary articles made of steel. Rail failures are greatly dependent on climate and locality. A railroad official of a road in the north-west claimed he could examine his monthly record of broken wheels and rails and determine the date at what point on the road they had extremely cold weather. This statement is borne out in drop testing rails at temperatures from 50° Fah. to 100° Fah. below zero, which showed a pronounced falling off in resistance to shock. In these tests, the added effects of a frozen roadbed could not be studied. Another western road had two and a half times as many rail failures annually per mile of track on one portion in which the sub-grade was largely clay, as compared with another portion of track on a sandy, porous sub-grade, the traffic and rail section being the same in each case. An official of this road stated, "These facts seem to confirm the statement 'there are indications that rail failures are a question of geography.'" An experiment under my supervision verifies this statement, when I found a piece of track about 500ft. long in which rails, splices, and fastenings failed much more rapidly than in the track on either side. The track was perfectly straight, the fill for sub-grade of the same material, the rails, ties, and ballast alike. No apparent reason could be found for the difference in performance, until it was pointed out that the railroad crossed an old, abandoned canal bed, where the ground had remained soft and swampy for years.

Transverse fissures appear as a new rail disease. Apparently composition is not responsible for their occurrence, as they are found in both segregated and unsegregated rails and from every part of the ingot. Lack of ductility of the steel cannot be charged against it, as of 102 rails removed for transverse fissures, more than one-half had an elongation of over 10 per cent., while one of the rails, giving only seven months' service, had 14 per cent. elongation. From incomplete investigations made, transverse fissures appear to be a kind of detailed fracture, the result of a combination of cold rolling or working of the metal in service and vibration of the rail. The results so far indicate they may be produced on a new or worn rail at any point desired. If this can be proven, the answer is obvious. A rail must be so strong or so well supported that it cannot vibrate. I have made many enquiries, but have not heard of a case of a transverse fissure on a well-supported rail, as on a bridge. Some engineers go so far as to recommend that a rail be laid on a longitudinal girder to support it.

Rail durability can be obtained by several methods. Alloy steels, of which manganese steel is a good example, is one method, but its cost, except for special locations, as yards, switches, terminals, or congested-traffic points, is prohibitive. Heat-treated rails of alloy or carbon steels have shown less

* Abstract of paper read before the American Iron and Steel Institute, New York, May, 1916

wear in the few service tests made to date, and are another example of possible improvement in rail durability. Rail improvement will be made. This result will probably be reached by using the best steel obtainable, an increase in size of section, and the best possible maintenance. A combination of these factors should lead to a settlement of the rail question.

BRITISH INDUSTRIES AFTER THE WAR.

THE Board of Trade announce that, in view of the wide range of the industries included within the scope of the Committee appointed to deal with the position of the iron, steel, and engineering trades after the war, and in order to expedite the enquiry, the President has decided to sub-divide the work of the Committee between two committees, dealing with the engineering trades, and the iron and steel trades, respectively. He has accordingly appointed the two following committees:—

For the Engineering Trades—Sir Clarendon Hyde (chairman); Mr. Arthur Balfour (Sheffield); Mr A. J. Hobson; Mr. W. B. Lang; Sir Hallewell Rogers; Mr. H. B. Rowell; and Mr. Douglas Vickers. Mr. A. F. Ilsley will act as secretary to the committee.

For the Iron and Steel Trades—Mr. G. Scoby Smith (chairman); Sir Hugh Bell, Bart.; Mr. Archibald Colville; Mr. James Cox; Mr. James Gavin; Mr. George Mure Ritchie; Mr. Henry Summers; and Mr. Benjamin Talbot. Mr. C. R. Woods, of the Board of Trade, will act as secretary to the committee.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Distillation of heavy oils, oil residues, and bitumens. Hall. 4598.
Method of working internal combustion engines. Ferguson. 6419.
Method of regulating and measuring the proportional flow of liquids or liquids and gases. Lea. 9067.
Gear-rolling machines. Anderson. 9154.
Tool holders for lathes and similar machines. Schellenbach. 9290.
Metallic packings. Trist. 9356.
Rotary pumps and engines. Petter. 9431.
Rotary pumps and motors. Marks. 9501.
Mechanism for converting reciprocating in rotary movement. Candelon. 9638.
Method of and apparatus for extracting and discharging condensate and air from a condenser. Ges. fur Kalteindustrie. 9721.
Carburetters for explosion motors. Lacharnay. 9861.
Means for supplying fuel to internal combustion engines. Thomas, Berk, & Morgan. 9973.
Metallic packing. Bowie & Samples. 9998.
Cutting off lathe. Swinney. 10758.
Railway rail joints. Macer. 11133.
Internal combustion engines. Cox. 12251.
Drill tool sharpening machines. Christiansen. 12467.
Testing machines with recording apparatus Saml. Denison and Son, Ltd., Denison, and Brown. 14305.
Machines for casting metallic tubes. De Lavaud & Arens. 14936.
Oil atomisers. Brown & Hall. 16011.
Tilting crucible furnaces. Alldays & Onions Pneumatic Engineering Company, and Nicholsen. 16394.
Flexible tubular joint or coupling. Kruger & Kruger. 18002.
Chains. Hughes. 18097.

1916.

Universal joints. Titania Schriebmaschinen Ges. 528.
Method of and apparatus for producing ribbed pipes and tubes. O. V. Cardell. 880.
Pistons for internal combustion engines. Humber, Ltd., and F. T. Burgess. 1741.
Devices for automatically controlling the lead of ignition in internal combustion engines. L. Renault. 1765.
Rotary pneumatic drills. W. J. Mellersh Jackson. 2910.
Combined variable speed gears and starter for internal combustion engines. F. M. Summerfield. 3072.
Centrifugal pumps. G. & J. Weir, and C. R. Lang. 6155.

ELECTRICAL, 1915.

Armour clad electric switches. Berry & Markham. 7979.
Telegraph systems and apparatus therefor. British Insulated and Helsby Cables, Ltd., and Harrison. 8712.
Means for driving dynamos. Langdon-Davies, Soames, and Naamlooze Vennootschap. 9282.
Electrical selectors or impulse responders. Relay Automatic Telephone Company, and Bygrave. 9345.
Induction motors. British Thomson-Houston Company. 9557.
Electric motor-control systems. British Thomson-Houston Company. 9836.
Switches for resistances. Kamm. 12516.
Electric arc lamps. Mackay. 12994.
Sparking plugs. Guinness. 13088.
Sparking plugs. Joly. 13733.
Electric adaptors. General Accessories Company. 15460.
Operating rotary converters and other alternating-current machinery. Railing & Garrard. 15681.
Combination electric turn switch and wall plug. Begg. 15922.
Electric incandescent lamp holders. Bennett. 16349.

1916.

Means for controlling electric motor circuits. Igranic Electric Company. 1248.
Electrical systems for engines. C. F. Kettering, and W. A. Chryst. 4688.
Magneto-electric machines. J. W. Miller, and M. Collard. 5085.

METAL QUOTATIONS.

TUESDAY, JULY 18TH.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled..	1/4⅝ per lb.
,, tubes (brazed)	1/5 ,,
,, ,, (solid drawn)	1/3 ,,
,, ,, wire	1/4⅛ ,,
Copper, Standard	£88/–/– per ton.
Iron, Cleveland	82/6 ,,
,, Scotch	— ,,
Lead, English	£29/5/– ,,
,, Foreign (soft)	£28/10/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	29¾d. per oz.
Spelter (American)	£44/–/– per ton.
Tin, block	£163/10/– per ton.
Tin plates, I.C.	32/– per box.
Zinc sheets	£75 per ton.

THE SCREMERSTON RAILWAY ACCIDENT.

THE report issued by the Railway Department of the Board of Trade into the derailment of the passenger train from King's Cross to Edinburgh, which occurred on the North-eastern Railway on May 22nd last, as the train, with 175 passengers, was approaching Scremerston Station, and caused the tender and seven leading vehicles to leave the rails, though fortunately without injuring anyone, attributes the accident to failure of the spring hanger on the tender.

Lieut.-Colonel Donop, who made the enquiry, states that "The broken hanger was of wrought iron, 1⅞in. diam., and from the portion of it which remains it is evident that the breakage was due to an internal flaw in the metal; it is doubtful whether this flaw could ever have been detected by inspection, but in any case it could not have been seen unless the hanger had been entirely removed from the vehicle, as the portion of it where the flaw occurred was covered by a bracket, through which it passed. The company state that the present form of spring hanger and bracket has been in use for many years, and that there have been very few failures with them. In the face of this accident, however, it would seem advisable for the company to consider whether any improvement can be made in the design, with the view of either providing additional strength or of facilitating inspection."

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Lecturer on Metallurgy, and demonstrator on Metallography at the Royal Technical College, Glasgow.

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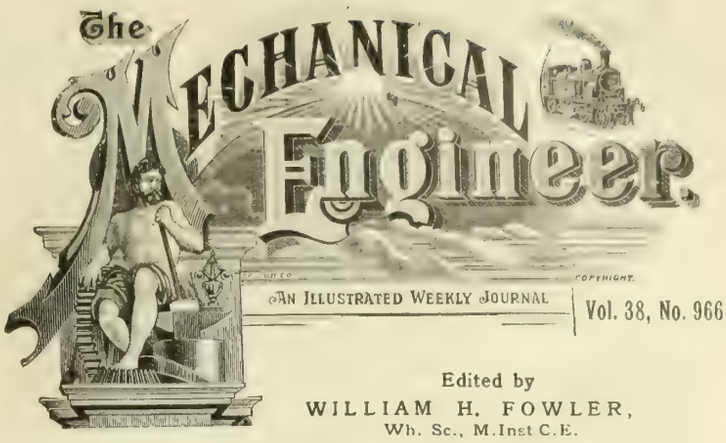

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Failure of Diesel Engine Crankshafts.

THE Diesel Engine Users' Association is doing excellent service, both to users and makers, by the admirable papers and discussions it has initiated respecting the special difficulties and troubles experienced with Diesel engines. Their remarkable high-fuel efficiency goes without saying, and though the increased price of oil has detracted largely from their intrinsic economy, even from the fuel point of view, as compared with steam engines, and, therefore, diminished their chances of supplanting the latter to the extent which their advocates first thought, they still retain special features which ensure certain fields of employment as their own. On the other hand, it would be idle to pretend that the engine has not acquired a reputation for liability to serious and unexpected troubles in the way of compressor explosions, as well as expensive breakdowns from failure of crankshafts. For a time these were belittled by makers, but the experience of insurance companies in this connection became eventually too expensive to permit of the truth being minimised, and full discussion and patient investigation replacing commercial bluff is slowly revealing the methods of overcoming the troubles and difficulties which have beset the earlier path of this in many ways excellent type of prime mover. A typical example of the way in which these are now dealt with was illustrated by the special investigation and discussion instituted by the association, with regard to the explosion of a Diesel engine compressor some little time ago at the Smithfield Markets. The light thrown on this, and incidentally other similar failures, by the special report prepared by Mr. P. H. Smith, was most instructive, and greatly to the advantage of both makers and users. An equally valuable contribution regarding another weak point in the construction of Diesel engines has also been made by Mr. Smith in a paper read before the last meeting of the association on "Precautionary Measures to Adopt to Prolong the

Life of Diesel Engine Crankshafts," reproduced *in extenso* elsewhere in this issue. The object of his paper is to show that the life of these crankshafts is mainly dependent on the engineer-in-charge, and that by taking reasonable and simple precautions it may be prolonged indefinitely. Without accepting this dictum in its entirety it may be conceded that in the main it is true. Crankshaft failures have certainly given rise to much anxiety and expense. Mr. Smith attributes all the shaft failures he has met with to lack of alignment of the main bearings as a result of unequal rates of wear, though in some cases negligence during erection, and in others defective foundations, have been primary or contributory causes. In his paper Mr. Smith limits himself entirely to a discussion of the 4-cycle vertical type of engine, and it would appear from his experience that the type of engine least liable to shaft fracture is the 3-cylinder, and the one most liable the 4-cylinder. The manner in which these shafts fail is almost invariably through the crank webs, and in 4-cylinder units the web which fractures is almost invariably the fourth, counting from the end furthest from the flywheel. Mr. Smith's conclusion as to the source of these failures is based upon a study of a particular 4-cylinder type plant installed by a continental firm about nine years ago, and comprises data carefully compiled during four years of continual observation. The details as to the leading proportions of the engine and other matters are fully recorded in the paper, along with the results of his observations, and therefore we need not repeat them here. It is sufficient to say that they fully bear out the conclusion at which he arrives, and show how mysterious and apparently inexplicable troubles yield to patient and painstaking observation, just as simple precautions serve equally to prevent their recurrence. The prevention of shaft fractures resolves itself very largely into preservation of the alignment of the shaft, and Mr. Smith gives some good practical hints with respect to the method of securing this, along with some suggestions respecting strength and proportions of crank pins and bearings which, in view of his special experience, makers and users would do well to take note.

DESIGN AND MAINTENANCE OF LOCOMOTIVE BOILERS.*

THE modern locomotive being called upon to maintain high speed, with heavy and increasing train loads, and to meet greater demands for steam, the design and maintenance of boilers would seem to take precedence over any other part of the locomotive. That locomotive designers are aware of this was evident from the various means by which a number of roads are endeavouring to meet these conditions. Among the many devices tending to show the efforts in this direction may be mentioned a firebox composed of sectional U-shaped plates, with similar wrapper-sheet construction, riveted together, which eliminates staybolts; another firebox which consists of squared water tubes, expanded into water and steam drums at the top and a water leg at the bottom eliminating staybolts on the sides of firebox; a corrugated firebox; also the several types of water-tube locomotive boilers; devices to improve the circulation around the firebox; various forms and adaptations of combustion chambers and brick arches, and the almost universal adoption of superheaters.

The most generally adopted improvement in fireboxes appears to be the use of combustion chambers, either of the ordinary type or of special construction, having a bridge wall with air inlets. In some cases the adoption of combustion chambers has been due to a desire to avoid excessively long flues, while others have considered that the construction is desirable from its being inducive to longer flame travel, increasing firebox temperatures on account of the more complete combustion obtained. The increase in the ratio of firebox volume and grate area is held to be beneficial, producing better steaming boilers, while the improved combustion has the effect of eliminating black smoke. It does not appear that the maintenance and repair with combustion chambers is greater than is the case with the ordinary construction, while the life of the flues is greatly increased by their use.

There appeared to be little experimental data on the relative evaporative performance of boilers with or without combustion chambers. The firebox design being recognised as of paramount importance, there has been a general trend toward wider water spaces, about 4½in. to 5in. for the sides and 5½in. to 6in. at the front being representative practice. Firebox door flanges have been given considerable attention, the majority of opinion favouring flanging the sheets toward each other; the joint in many cases being welded, with beneficial results, from the elimination of rivets, with their tendency to collect mud. Some state that the welded method is cheaper than the riveted joint. Cross braces are used as a matter of necessity on Belpaire fireboxes and boilers with flattened surfaces and to some extent on crown bar boilers.

The use of flexible staybolts, instead of tee bars and sling stays, to support the front end of firebox has become quite general, and the results have been satisfactory. In order to obtain proper bearing for flexible radial stays which are at a sharp angle with the wrapper sheet, one road reported having pressed out bosses in the sheet, while another road builds up bosses by autogenous welding. The results, giving sufficient full threads through the sheets for the bolts, have been very satisfactory. Regarding venting crown sheet in case of low water, two roads report that on coal-burning locomotives they omit the button heads on four front transverse rows of stays. Another reported omitting button heads on the sixth, seventh, eighth, and ninth rows back from the back flue sheets for the same purpose. The majority, however, do not make any allowance for this contingency.

Regarding the relative value of firebox and tube heating surface, there appeared to be little data derived from tests. However, the accepted value assigned to firebox and flue heating surface, respectively, on basis of evaporative capacity averages about 6 to 1, with special designs of firebox claiming a ratio as high as 12 to 1. The most effective ratio of firebox volume to grate area seems to be approximately from 5·5 or 6 to 1 for bituminous coal and 4·5 to 4·85 to 1 for anthracite coal.

The use of long flues is not favoured, for, while the total evaporative capacity of the boiler may be increased by their use, the rate of evaporation per unit area of heating surface is lower, and discounts the theoretical increase in capacity. In this connection tests show conclusively that there is a great variation in the evaporative value of the boiler tube, about one-half of the heat being transmitted in the first quarter of the tube length. It appears that a proportion of tube length to diameter of 100 times the inside diameter is most satisfactory. Longer tubes do not require any greater spacing than reasonably short tubes. The addition of superheaters is quite general and superheaters are likely to be used on all new equipment, with the possible exception of some few roads which are not certain about switch engines. The ratio of superheating surface to total saturated heating surface seems to vary from ·198 to ·29, the average for modern power being about ·27 to ·29 for boilers with combustion chambers and ·20 to ·22 for boilers without combustion chambers.

In a general way it may be deduced that in modern practice the built-up type of dome is being generally abandoned in favour of one-piece pressed-steel domes. In regard to the elimination of boiler seams, no general effort has been made, although one member reports satisfactory results from combining the throat sheet and bottom half of last course. In almost all cases firebox sheets, as well as wrapper sheets, are made in one piece. There does not appear to be any development along the lines of welding circumferential seams. The support of the back end of the boiler above frames seems to be satisfactorily met by either vertical expansion plates or by expansion shoes.

The use of cylinder volume as a basis in designing locomotive boilers, as outlined by this association in the proceedings of 1897, has, with the development of new and larger types of locomotives and superheaters, proved unsatisfactory, and your committee is of the opinion that better results are obtainable from ratios based on cylinder horse-power.

The most interesting feature brought out by the committee in connection with boiler maintenance is the wide adoption of autogenous welding. The welding of flues into flue sheets, of firebox seams, and the application of patches varying in size

* Report of a committee presented at the annual convention of the American Railway Master Mechanics' Association, June, 1916.

from small crack and pitting repair plates to half side sheets and back heads, marks a radical and economical means of handling what has heretofore been a difficult and expensive problem. Both electric and acetylene welding processes have been used, but we are unable to determine which method gives the best results, as it seems to be largely a matter of opinion. Firebox seams have been welded successfully, one road reporting 14 engines by the electric process, while another road reports three engines with all seams welded by the acetylene process. Several roads report having side sheet seams welded, with little or no trouble experienced. Occasionally it has been necessary to re-weld a seam, on account of opening up.

Among the other uses to which the electric and oxy-acetylene processes have been put is in cutting off old smoke boxes, burning off staybolts, instead of nicking and breaking them, and to loosen the caps on flexible staybolts to permit of easy removal without damaging threads. The autogenous processes of welding have recently been used to quite an extent for patching in fireboxes. Some of the replies indicate that welding can be done at about 40 per cent. of the cost of riveting; others report very little difference in cost. The methods of patching are still an experiment on most roads; others are reporting satisfactory results. The methods preferred seem to be a matter of opinion; the patches are of all shapes and sizes; some are welding by lapping the plates, others by bevelling the patch and plate and filling in the groove, and others report patches being boxed out or bulged with a corrugation for expansion, but from the replies it is impossible to draw a conclusion as to the best way or method. Fire-door openings have also been replaced by welding, with success.

The practice of welding cracks in the knuckle of flue sheet is quite extensively used, in most cases the welding being done on both sides of sheet. Two roads cut out the crack and weld in a patch, but in the majority of cases the crack is filled up without patching. While some roads report welding in half side sheets and half back heads, with satisfactory results, the practice has not yet become general. One reports welding brick arch studs on side sheets of firebox, with success, but no welding-in of arch tubes has been reported.

The methods of safe-ending superheater flues, as reported, are rather uniform, the usual way being to cut off at the small end, scarf, apply safe end, and weld in flue-welding machine. A few roads report that they have welded safe ends by the electric or oxy-acetylene process. In this method, after scarfing, the flue and safe end are separated about $\frac{1}{8}$in. and the opening filled up, rotating the flue during the process. It seems to be accepted practice to avoid the use of more than one weld in a superheater flue at a time, which is accomplished by increasing the length of safe ends in successive applications, the old weld being cut off and a longer safe end used. Few roads weld safe ends to the enlarged portion of the flues. Results are in most cases reported as being satisfactory.

The usual practice in setting tubes appears to be, for the back end, to insert a copper ferrule in the hole, then roll, expand, and bead the flue, after which the joint is cleaned and welded lightly on the edge of the bead. One road reports that copper ferrules are not used, nor flue beaded, but welded in by the electric process, which is indicated to be the most generally used in this class of work. Flues in the front flue sheet are not welded, but rolled, and about 10 per cent. beaded.

While a few roads are rebuilding old locomotives and converting consolidation types to Mikados, and Prairie types to Pacific types, there is no general trend in this direction. Many roads are applying superheaters to their more modern types of saturated engines, and in some cases at the same time eliminate old styles of staying, bracing, &c. The application of combustion chambers, brick arches, and outside valve gear has been reported by several members. On engines having cylinders smaller than 20in. diam., it has not as a rule been considered advisable to apply superheaters.

In view of the development of the locomotive, it is the opinion of the committee that the ratios of 1897, being unsuitable, should be superseded by a method of calculation which will meet the variable conditions imposed by modern practice. The reports indicate a wide departure from the recommended practice of 1897. Ratio of grate area in square feet to volume of two cylinders in cubic feet, for simple passenger or freight locomotives, should not be less than: four for large anthracite coal; nine for small anthracite coal; and three for bituminous coal. From the replies received, for modern power these ratios have been increased 23 per cent.

The ratio of heating surface in square feet to grate area in square feet, for simple passenger and freight locomotives, should not be less than: 40 for large anthracite coal, 20 for small anthracite coal; and 60 for bituminous coal. From the replies received, for modern power these ratios have been increased 28 per cent.

The ratio of heating surface in square feet to volume of two cylinders in cubic feet, for simple passenger or freight locomotives, should not be less than: 180 for large anthracite coal; 200 for small anthracite coal; and 200 for bituminous coal. From the replies received, these ratios for modern power have been increased 34 per cent.

The committee, therefore, submitted for adoption as recommended practice the following ratios based on cylinder horse-power:—

D Diameter of cylinder.
P Boiler pressure.
A Area one cylinder diameter.
Hp Horse-power.
TP Tractive power.
d Diameter of drivers.
S Stroke in inches.

(1) From weight limitation on drivers, and from service, type, &c., obtain the required tractive power.

(2) From tractive power, boiler pressure, stroke and size of drivers obtain diameter of cylinder.

$$D = \sqrt{\frac{TP \times d}{\cdot 85 \times P \times S}}$$

$$H\,p = \cdot 02120 \times P \times A \text{ for saturated steam.}$$
$$H\,p = \cdot 02290 \times P \times A \text{ for superheated steam.}$$

Maximum horse-power assumed to be reached at the following piston speeds: Saturated steam, 700ft. per minute; superheated steam, 1,000ft. per minute.

The following figures are based on reports from various testing plants and road tests made under different conditions, and are liberal and can be more than met under favourable conditions:—

(3) Estimate total steam per hour from:—

$H\,p \times 27{\cdot}0$ for saturated steam.
$H\,p \times 20{\cdot}8$ for superheated steam.

(4) Estimate total coal per hour from:—

$H\,p \times 4{\cdot}00$lbs. for saturated steam.
$H\,p \times 3{\cdot}25$lbs. for superheated steam,

based on coal containing 14,000 B.T.U. per pound, using a percentage factor for poorer or better grades of coal.

(5) Estimate size of grate from total coal divided by 120, or

$$\text{Grate area} = \frac{H\,p}{30} \text{ for saturated steam.}$$

$$\text{Grate area} = \frac{H\,p}{36{\cdot}9} \text{ for saturated steam.}$$

(6) Estimate evaporation of firebox, including combustion chamber and arch tubes, if used:—

Sq. ft. firebox heating surface $\times$ 55 = evaporation in pound per hour.

(7) Subtract (6) from (3) to obtain tube and flue evaporation required. Base evaporation in 10lbs. water per hour per square foot.

(8) To obtain percentage of boiler, divide total pounds of steam proposed boiler will evaporate by these formulæ by pounds of steam required.

(9) The ratio of firebox volume to grate area should be about 5·5 or 6 to 1, for bituminous coal; 4·5 or 4·85 to 1, for anthracite coal.

The ratio of length to diameter for tubes should be about 100 to 1 $\times$ internal diameter, which for 2in. tubes would give a length of about 16ft. and for $2\frac{1}{4}$in tubes about 18ft.

The ratio of superheating surface to total saturated heating surface should be, without combustion chamber, about ·22, and with combustion chamber about ·29.

The committee was greatly impressed by the possibilities of the processes of autogenous welding for boiler maintenance, and offered the suggestion that a committee of the association be appointed for the purpose of assembling and analysing all available information on this important subject, with a view to arriving at standard methods of using the processes, and to develop further the present largely experimental work along this line.

DIESEL ENGINE CRANKSHAFTS.*

BY PHILIP H. SMITH.

THE object of this paper is to show that the life of a Diesel crankshaft is mainly dependent upon the engineer-in-charge, who may take certain reasonable and simple precautions to prolong its life indefinitely. All shaft failures I have investigated owe their origin to lack of alignment of the main bearings. This is usually the result of unequal rates of wear of the several bearings supporting the shaft, though in some cases it can be traced to negligence during erection, or, in older engines, to defective foundations.

So far as this paper is concerned, I am limiting my remarks to the case of bearings wearing away unequally on 4-cycle vertical engines. Engines which drive through a belt or through ropes appear to be less liable to fracture the shaft than engines direct coupled to generators. This is probably due mainly to the tension of the drive causing the reversal of thrust on the shaft to take place without shock. The type of engines least liable to shaft fracture is the 3-cylinder, and the worst is the 4-cylinder normally, though the 2-cylinder runs it a close second if fitted with a very heavy flywheel. I have no definite knowledge of the relative life of the 6-throw crank, partly because there are few running and partly because those which are running have not been installed more than three or four years.

Almost without exception Diesel shafts have failed through the webs, the crack starting at the centre and working outwards, the time elapsing between the first appearance of the fracture and its complete failure generally extending over many weeks. Only two exceptions occur to my mind where the shaft has failed through the pin or journals, and in both these cases the shafts obviously failed through being under-proportioned at the part which fractured, though even in these cases some considerable lack of alignment was traced.

As regards location of fracture, either web may fail in the single-cylinder units. In 2-cylinder engines, web 4 fails most frequently (the webs being numbered consecutively, commencing from the end furthest from the flywheel). In 3-cylinder units the fracture occurs either in web 1 or 6, and in 1 as often as 6. Sometimes both fail simultaneously. I have no knowledge of any other webs failing in a 3-cylinder unit, though perhaps some of the members of this association may be able to refer me to cases which have hitherto not been brought to my notice. In 4-cylinder units it is, I think, an almost invariable rule that web 4 fractures.

On account of its extra susceptibility to failure, and particularly because it always appears to fail in the same place, I have paid more attention to obtaining data from 4-cylinder engines than any other type. In this I have been fortunate in securing the co-operation of one of your members, and I have pleasure in placing before you data carefully compiled and extending over four years of continual observation on two engines of the 4-cylinder type. The value of these data will become more evident after I have described the plant and given its history, and then followed this up by going more deeply into the subject.

The plant was installed about nine years ago, and comprised two continental engines of four cylinders each, the cranks being arranged as shown in Fig. 4, viz., up, down, down, up, as contrasted with the usual arrangement in this country, up, down, up, down. The cylinder dimensions were 415 × 600 mm., and the engines ran at 170 revs. per minute, developing 320 b.h.p. each. The flywheels weigh about 8 tons each, and a bearing is interposed between the flywheel and a direct-current generator. Expressed in relation to the cylinder bore (D), the main dimensions of the shaft are:—

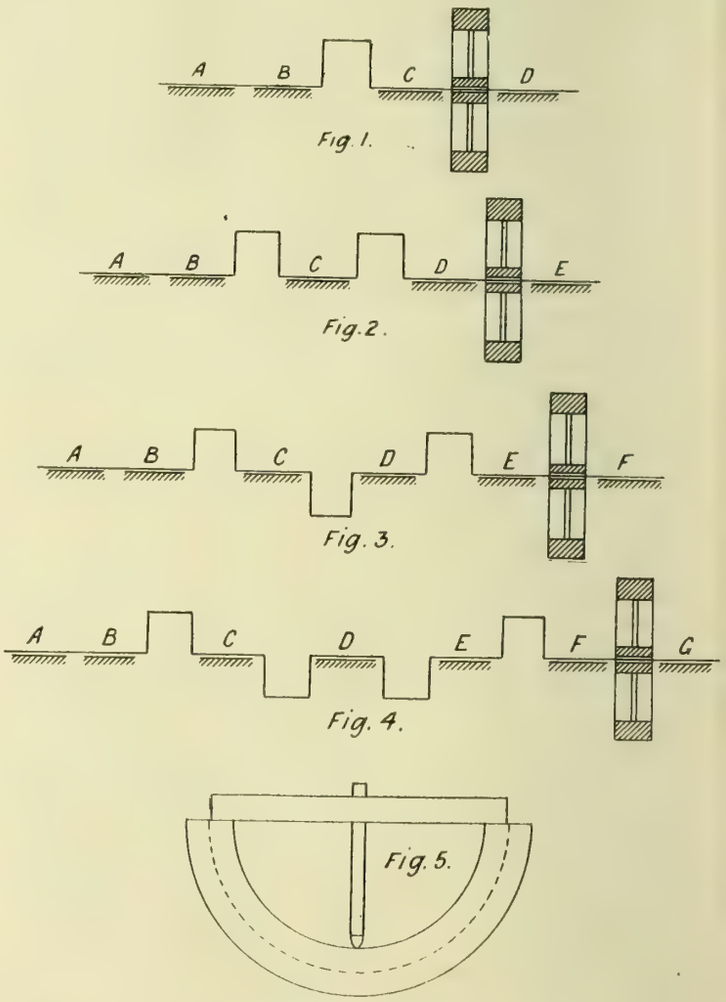
Diameter of journals and crankpins...	0·53D
Thickness of crank webs	0·265D
Length of pin	0·53D
Length of main bearing	1·1D

The shaft is therefore on the weak side, but to this I will return later. I am not aware that an analysis of the steel is obtainable, but I have the analysis of a similar shaft which failed about 11 years ago, viz.:—

Tensile strength	32·88 tons per sq. in.
Elongation on 3in.	19·3 per cent.
Reduction in area	20·4 „
Carbon	·327 „
Silicon	·169 „
Manganese	·767 „
Phosphorus	·057 „
Sulphur	·086 „
Copper	Trace.

The metal is quite good of its class. As regards the history of the plant, the engines ran for the first four or five years on a very irregular load, and then a buffer battery was introduced, which has had very beneficial results as regards smoothing out the irregularities usually accompanying a comparatively small tramway load.

One engine broke its shaft about four years after its installation, and the other after about five years. In both



DIESEL ENGINE CRANKSHAFTS.

cases web 4 failed. These shafts were replaced by others obtained in England. The tensile strength of that now in No. 2 is about 32 tons, while that in No. 1 is 40 tons per square inch. After the new shafts had been bedded in, the engineer took out the under halves of the bearings and measured down from the facings to the white metal in the manner shown in Fig. 5. Thereafter, the bearings were measured every year, and thus the actual wear has been regularly recorded for 3½ years in the one case and for four years in the other.

I submit the results in curve form for your consideration (Fig. 6). A casual glance at the lower curve taken from No. 1 engine explains why the 4-cylinder engine with this arrangement of cranks fractures through the webs of the second cylinder. This curve is characteristic of 4-crank engines. The upper curve relates to No. 2 engine, and instead of bearing C showing the greatest wear, the wear is actually less

* Paper read before the Diesel Engine Users' Association, July 12th, 1916.

than in the adjacent bearings B or D. I was unable to explain this until we recently re-aligned the shaft. Then it was noticed that bearing C is appreciably eccentric to bearings B and D. Hence, in the usual way of bedding in a shaft, the probability is largely in favour of bearing C having been scraped too low, and thus, for some time, bearing C would not be submitted to its fair share of the load, and therefore did not wear away as fast as the adjacent bearings, which were taking more than their fair share.

It may be asked why the rate of wear is so much greater in the one engine than in the other, and the only explanation which I can give is that one engine is situated right opposite double doors leading into a dusty yard paved with ashes. This engine shows the greatest amount of bearing wear, and it protects the other engine to a large extent. Incidentally, I would mention in passing that there is another door leading outside the building, and the engines lie in a direct line with both. A similar lay-out occurs to me in the South of England, where bearing troubles have been experienced, and where a shaft has failed, only in this case sand replaces ashes.

Now, as regards precautions to be taken to prevent a shaft from breaking, I will particularise by explaining how the shafts of the two engines under consideration were re-bedded, and the application of the principle can be made general. The engine was stripped right down, excepting only that the flywheel was not taken off the shaft until it was definitely proved that its weight distorted the shaft. Then it also was removed. The bearings were found to have the metal loose and cracked, and the spare set was substituted, care being taken to employ one grade only of white metal throughout. The shaft was bedded in the usual way up to a certain point, but to complete work, bearing C was left a shade high and bearing A was left a shade low. Finally, and this is very important, the top caps were filed down, so that the journal ran in the bearing with running clearance only.

Thus the perfect alignment of the shaft was assured, and, before re-assembling the engine, we micrometered the thickness of metal on each bearing interposed between the shaft and bedplate. This has been recorded, and now from year to year we can re-measure this thickness, and so obtain the relative rates of wear in each bearing. That which is worn most will constitute the datum, and the data will show exactly how much must be scraped off the "high" bearings in order to re-introduce conditions of minimum stress on the shafts. I recommend the micrometer method as being less liable to error than the method already described, though I would also mention that care must be exercised even with the micrometer method, as loose white metal falsifies the reading, which will appear too large.

This system of assuring perfect alignment of the shaft will appeal especially to those engineers who have no reserve plant, and who have to get repairs done during the week-end. Thus, if the engine were a 4-cylinder, I should take out bearing C first and micrometer it. Look up the log-book and ascertain how much it has worn since the shaft was last re-aligned. Then take out bearing A, micrometer it, and ascertain the extent of wear in the same period. If it has worn down $\frac{8}{1000}$in. and bearing C has worn down $\frac{12}{1000}$in., then scrape down bearing A $\frac{4}{1000}$in. more, re-bed it to the shaft, or, preferably, to a special dummy journal, and then replace it. Treat all the bearings in like manner. If the engine is a 2-cylinder, or a single-cylinder unit, then probably the bearing adjacent to the flywheel is most worn. It therefore should be taken out first, measured up, and replaced, scraping only if found "high" at one end. Then take out the other bearings and scrape them in accordance with the data obtained. In the case of a 3-cylinder engine, the probability is largely in favour of bearing B being the lowest, and this, therefore, should be taken out first.

Thus, where plant is not in excess, the engineer can re-adjust a bearing each week-end until the whole set is completely put in order, and he runs very little risk of heated bearings if he is careful. The system has its limits. It would not do to apply it in this manner if rate of wear were very variable.

As I have explained it, it is necessary to dismantle the whole engine to make a good start with the system. I doubt if there is a short cut method by which one can absolutely ensure acquiring the data relating to conditions of minimum stress in the shaft. If, however, the engine has been very carefully erected, and is not more than a year or two old, then one may exercise his discretion and assume that any large differences in the thickness of the main bearing shells is due to difference in rate of wear. This, however, involves the personal equation, and cannot therefore be usefully discussed.

As regards the subsequent adjustment, running clearance of main bearings, it is not usually feasible to measure this with feelers, so one has to have recourse to other methods. Where possible, I prefer to feel the lift in each bearing, and let the cap closer and closer until the bearing either heats (in which case scrape out the cap) or until the lift just disappears.

However, one may have recourse to leads so long as they are considered only as a means of obtaining the *relative* and not the absolute clearance in a bearing. In the ordinary way, if one use 20 or 21 gauge lead wire, running clearance will be right if the lead squeezes out to $\frac{8}{1000}$in. or $\frac{9}{1000}$in. thick. If one uses 16 gauge, then this may squeeze to about $\frac{10}{1000}$in. or $\frac{12}{1000}$in. thick. The actual clearance is probably only $\frac{4}{1000}$in. to $\frac{6}{1000}$in. The difference between real and apparent clearance depends upon a multitude of factors which we need hardly discuss here, but we must bear in mind the fact that leads do not show the true clearance in a white-metal bearing.

Finally, a few words on the best proportion of shafts.

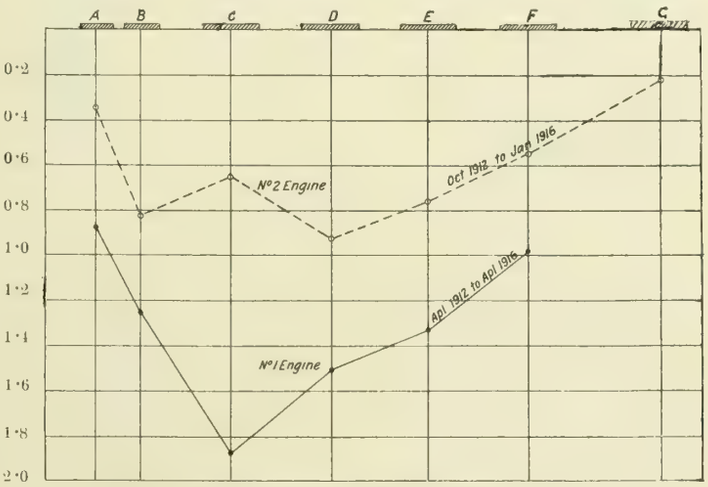


FIG. 6.—CRANKSHAFT BEARING WEAR.
Bearings of 4-cylinder Diesel engine lettered as per Fig. 4.

You cannot alter these on unfractured shafts, but perhaps some of the manufacturers will be guided by the recommendations I am about to make, if they are sure of your co-operation. The cylinder bore being expressed as D, the most amply proportioned shaft I have yet measured is as follows:—

Diameter of journals and pins	0·6D
Length of main bearing	0·9D
Length of big end pin	0·6D
Thickness of web	0·33D

At least two of these have broken, but that was through bad initial erection. The original Diesel shafts were made in 32-ton steel to the following proportions:—

Diameter of pins and journals	0·51 to 0·525D
Length of main bearings	1·1 to 1·2D
Length of big end pin	0·51 to 0·525D
Thickness of web	0·25 to 0·27D

The shaft I would propose, if my firm's system of re-alignment is adopted and your hearty co-operation is assured, is the following:—

Tensile strength, not less than 34 tons.
Ductility not less than 25 per cent. in 2in.
Diameter of pins and journals, 0·525 to 0·54D.
Length of main bearings, 0·75 to 0·8D.
Length of big end pin, 0·525 to 0·54D.
Thickness of webs not less than 0·32D, but centre to centre of cylinder made minimum possible, and any excess over the proposed length of pin and journal to be put into the webs.

Fillets to be not less than one-tenth the diameter of the shaft. This shaft is comparatively light, but it possesses the following advantages: (1) The fuel consumption of the engine is reduced; (2) initial cost and cost of upkeep is reduced; (3) the bearings will run cooler, other things excepting pressure per square inch being equal, for it is high peripheral speed rather than high pressure which causes bearings to heat; (4) lubrication costs will be reduced.

However, the success or failure of such a shaft depends upon proper attention being given to its adjustment from time to time, and if this is not given, then it is merely a question of time before even the heaviest shaft will fail.

POWER IN ROLLING STEEL.

BY CHARLES M. SAMES.

SOME months ago the writer desired to obtain information on the power required to roll rectangular steel sections (*i.e.*, the "pure roll work," or that expended solely in deforming the heated metal) for application to a particular problem. As nothing on the subject could be found in the engineering reference works and treatises at hand, recourse was had to the results of the elaborate series of tests carried out in Germany some years ago by Dr. Ing. J. Puppe, and published in a volume entitled "Versuche zur Ermittlung des Kraftbedarfs an Walzwerken" (Düsseldorf, 1909), an English translation of which was brought out a year later under the title "Experimental Investigation on the Power Required to Drive Rolling Mills" (C. Griffin & Co., Ltd., London). Later work of Dr. Puppe, as published in "Stahl und Eisen," was also consulted, as well as the data given by Barton R. Shower in "Proc. A.I.E.E.," March 12th, 1909.

About 50 of these tables examined deal wholly or in part with rolling through rectangular passes, and of these 35 which are fairly representative of all, barring a few abnormal exceptions—have been studied. They have to do with basic Bessemer and open-hearth steel ingots weighing from 260lbs. to 8,200lbs., with sections ranging from 20 sq. in. to 320 sq. in., with rolling temperatures of from 1,960° Fah. to 2,300° Fah., with initial tensile strength (cold metal) of from 56,000lbs. to 112,000lbs. per square inch, and with reductions of area per pass of from 5 to 25 per cent.

Several methods of analysing the data were essayed, but the most consistent results were obtained by the use of a formula proposed by Victor E. Edwards before the Engineers' Society of Western Pennsylvania in 1913. This formula, slightly transformed, is:—

$$P = \frac{C W \log (A_1/A_2) \sqrt{D\,T}}{t}$$

in which P is the mean horse-power required for the pass in question; W = weight of ingot (or billet) pounds; A_1 (A_2) = sectional area of ingot before (after) rolling; D = external or pitch diameter of rolls, inches; T = thickness of ingot when leaving rolls, inches; t = duration of pass, seconds; and C is a coefficient.

In the 34 tables from Dr. Puppe's work (over 250 separate tests) a mean value of 12 was found for C. In 25 of these tables C ranged from 10·3 to 12·5, and the extreme values for all of the tables were 10 and 16. The first nine passes of Mr. Shower's table (all of the rectangular passes) give C = 12·3, which is well in agreement with the mean value of 12 obtained from Dr. Puppe's tests.

That the power required to roll steel decreases with an increase in the rolling temperature is shown by all of Dr. Puppe's results when the same quality of metal was used in two or more series of tests, but the exact influence of the mechanical properties of the metal rolled is not apparent from a study of the data accompanying the tables; the latter show, however, that the power required does not vary in the order of the tensile strengths of the cold ingots.

For preliminary calculation, then, C may be taken as 12, and assuming that this value is constant for each pass, and that the temperature at the first pass is around 2,200° Fah., reasonably approximate results should be obtained. For example, let it be required to determine the power necessary to reduce a 16in. by 16in. ingot 60in. in length (weight W = 4,163lbs.) to $8\frac{3}{4}$in. by 8in. in six passes, the pitch diameter of the roll being 40in. and its speed 60 revs. per minute. Table I. gives the results of the necessary calculations for the case where the percentage reductions for the several passes are roughly equal.

TABLE I.

Number of pass	1	2	3	4	5	6
Sectional area, square inch	204	165·75	133·25	107·63	84	70
Width × thickness, inches	16 × 12·75	12·75 × 13	13 × 10·25	10·25 × 10·5	10·5 × 8	8 × 8·75
Per cent reduction	20·31	18·75	19·61	19·23	21·95	16·67
Log (A_1/A_2)	0·09861	0·09018	0·09479	0·09275	0·10763	0·07918
$\sqrt{D\,T}$	1·462	1·441	1·704	1·676	2·0	1·89
Horse-power seconds ($P \times t$)*	7,202	6,492	7,520	7,766	10,753	7,476
Length of ingot, inches	75·29	92·67	115·27	142·72	182·86	219·43
Duration of pass, seconds	0·88	1·093	1·233	1·540	1·819	2·235
Horse-power (= P)	8,188	5,942	6,542	5,043	5,912	3,345

* Total horse-power seconds for all six passes = 47,210.

TABLE II.

Number of pass	1	2	3	4	5	6
Sectional area, square inches	216·8	181·57	149	119	93·625	70
Width × thickness, inches	16 × 13·55	13·55 × 13·4	13·4 × 11·12	11·12 × 10·7	10·7 × 8·75	8·75 × 8
Per cent. reduction	15·31	16·25	17·94	20·13	21·32	25·23
Log (A_1/A_2)	0·07218	0·07701	0·08586	0·09764	0·10415	0·1263
$\sqrt{D\,T}$	1·396	1·409	1·612	1·655	1·89	2·0
Horse-power seconds ($P \times t$)*	5,038	5,420	6,912	8,072	9,833	12,620
Length of ingot, inches	70·85	84·6	103·09	129·07	164·06	219·43
Duration of pass, seconds	0·853	1·012	1·136	1·402	1·671	2·183
Horse-power (= P)	5,910	5,354	6,083	5,756	5,884	5,781

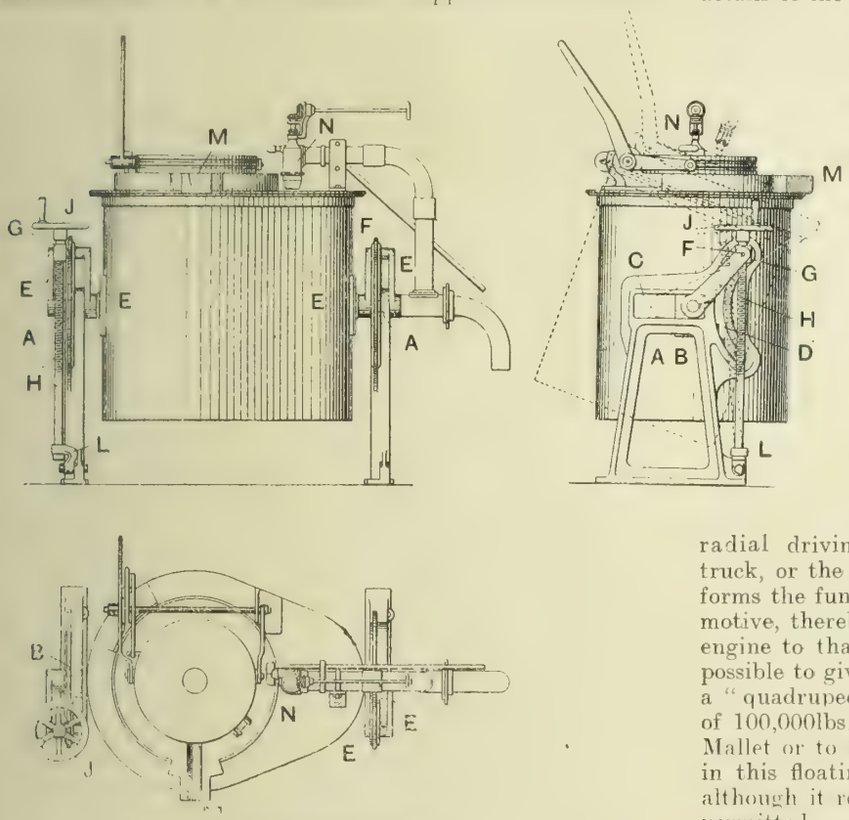
* Total horse-power seconds for all six passes = 47,985.

It is seen from this table that the draughts on the motive power range from 3,345 h.p. to 8,188 h.p.; but by a little manipulation of the percentage reductions, in which they are altered to an ascending scale, it is possible roughly to equalise these draughts, as shown in Table II., where the variation is reduced to the range 5,354 h.p.—6,083 h.p.

It is also seen that the total work in horse-power-seconds is practically the same for the two tables, although the orders and magnitudes of the percentage reductions differ considerably. The work expended also increases somewhat with a decrease in the number of passes employed in effecting the total reduction, or, what is the same thing, with an increase in the average percentage of reduction per pass, and vice versâ. For example, with calculations similar to those in Table II., but for four passes, horse-power-seconds = 49,690, an increase of 3·8 per cent.; for eight passes, horse-power-seconds = 47,000, a decrease of 1·8 per cent.; and for 12 passes, horse-power-seconds = 46,120, a decrease of 3·7 per cent.—"The Iron Age."

TILTING CRUCIBLE FURNACE.

THE crucible tilting furnace shown in the illustrations herewith, the invention of Messrs. Alldays & Onions Pneumatic Engineering Company, Ltd., Great Western Works, Birmingham, and Mr. E. W. Nicholson, has been designed with a view to simplify the construction and arrangement of parts for preserving the pouring lip or spout in the same vertical line during the tilting of the furnace, thereby rendering unnecessary the movement of the mould into which the molten metal is being poured. The furnace proper is provided with trunnions A at opposite sides, having upon them rollers B which occupy and work, when the furnace is tilted, in the horizontal slots C in the upper ends of the standards of the furnace. The trunnions A also have fixed thereon pairs of arms E, the arms at one side of the furnace being connected by trunnions F on opposite sides of a screw-box G on the screwed rod H which has on its upper end the wheel J



TILTING CRUCIBLE FURNACE.

by which the screwed rod H can be rotated. The lower end of the screwed rod occupies an eye in a swivelling bracket L pivoted to the bottom of the standard. One of the trunnions F has on it a roller which is accommodated and works in the curvilinear slot D in the standard at that side of the furnace. The arms E at the other side of the furnace are connected by a spindle having upon it a roller occupying the curvilinear slot in the other standard. On the rotation of the screwed rod H, effected by the turning of the wheel J, the screw-box G is lowered or raised, according to the direction of rotation of the screwed rod H, and the rollers occupying the curvilinear slots D in the standards are made to travel therein, the pairs of arms E being also turned, thereby effecting the bodily movement of the furnace and tilting of the same with respect to the frame-like standards, the motion of the furnace being such as to preserve the pouring lip or spout M always in the same vertical line. N is the gaseous fuel burner of the furnace by the flame from which the metal or alloy in the furnace is melted.

Manchester Association of Engineers.—The president of the Manchester Association of Engineers (Mr. F. W. Reed, of Craven Bros. (Manchester), Ltd.) and Mrs. Reed entertained the members and their friends at a garden party at The Grange, Reddish, on Saturday last, the guests numbering 250. An interesting programme of music and recitals, together with the fine weather, made the party a great success.

STEAM LOCOMOTIVE DEVELOPMENT IN THE UNITED STATES.

THE 19th annual convention of the American Railway Master Mechanics' Association was held at Atlantic City, N.J., on June 19th. The proceedings were opened with an address by the president, Mr. E. W. Pratt, assistant superintendent motive power, Chicago and North western Railway, Chicago, who, in the course of which, dealt with locomotive development in the United States during the past year as follows:—

Even now, with the remarkable installations of electric propulsion in certain restricted areas, there yet remains but one self contained power plant that will meet the demands of service and economy in this land of magnificent distances and low unit costs of transportation. Nor will we, doubtless for years to come, see aught but the occasional supersedence of the steam locomotive by electric power or by the internal-combustion engine. Hence it is all the more essential to-day that the details of the steam locomotive—this complete power plant on wheels—be so carefully studied, improved, and perfected as to hold in the ascendency its well-deserved prestige, yet so modified as to overcome its deficiencies.

The past year has witnessed the almost universal use of the superheater and brick arch, but the refinements of the former are only just commencing. The high temperatures of steam have brought into more extended use the force feed lubricator, a custom quite general in European locomotive practice. There is evidenced a halt in the strife for larger and still more powerful locomotives of the articulated type, and yet the perfection of the mechanical stoker has increased the human limitations therein so that some cause other than the stoking of the boiler must be sought as the reason. Perhaps the articulated locomotive was only the means to an end which may now be accomplished in other ways. The floating or radial driving axle in conjunction with the two-wheel pony truck, or the trailer working in synchronism, practically performs the functions of a four-wheel truck in guiding the locomotive, thereby reducing the rigid wheel base of a ten-driver engine to that of an eight or six. This principle makes it possible to give a "centipede" the same facility track-wise as a "quadruped" or "biped" and gives promise of an engine of 100,000lbs. tractive force (or more) without resort to the Mallet or to the triplex idea. There is indeed great promise in this floating axle scheme or some developments thereof, although it requires a change in the restricted side play now permitted.

The use of multiple cylinders for compounding was halted somewhat by the equal and easier economy effected by the superheater, yet who shall say that the ideal of "compounding in one cylinder" may not be reached in the avoidance of condensation by superheat? Already there are designs for a large freight locomotive that is unique in many respects and is intended to accomplish just this desideratum—the cylinder will be relatively long, the boiler pressure and superheat high, and the maximum starting effort of over 80,000lbs. based upon approximately one-half cut-off.

There has been further progress in locomotive design in the way of giving greater attention to refinements and the tendency to reduce the weight of reciprocating parts and running gear is noticeable, but not to the fullest extent nor equal to the results obtained by our automobile friends. An expert designer has calculated that the heaviest and most modern 2—10—2 locomotive could be reduced in weight full 7,000lbs., or the equivalent of a boiler 2in. larger in diameter, by the use of carbon vanadium steel (not heat treated) which can be purchased in billet form at a slight increase in the price per pound premium and forged in any locomotive shop, only requiring annealing.

The development of the film feed-water heater and the possibility of passing 60,000lbs. of water per hour through such a device of size small enough to be made practicable on a locomotive gives rise to the belief that a marked economy may be effected thereby; for it has been demonstrated that an increase of every eleven degrees in temperature will represent

an economy of 1 per cent. The boiler being the limiting feature of the modern locomotive, no pains or expense should be spared to effect its improvement, and it is in that line that the greatest advancement in the art of locomotive engineering is to be expected.

The report of the committee appointed by the Chicago Association of Commerce on "smoke abatement and electrification of railway terminals," extending over a period of four and one-half years, was presented to the public during the past year and is probably the most elaborate ever made on this subject. In brief, the conclusion reached that the complete electrification of the steam railway terminals of Chicago would cost not less than $275,000,000, and is financially impractical under present-day conditions, and that although great progress has been made in recent years toward reducing the smoke from steam locomotives, the maximum results have not yet been attained. While the electrical engineer has tremendous and difficult problems to meet in the enormous first cost for installation, extraordinary fixed charges, and relatively low load factor, he is making rapid strides with respect to reducing the cost per kilowatt hour by power plant improvements, and the steam locomotive must forge ahead quite rapidly in order to maintain its prestige. Through the limitations of clearances the boiler is bound to be the controlling factor in the development of the steam locomotive, and while we should produce the maximum hauling capacity per unit of total weight at the minimum cost per pound of draw bar pull, consideration must also be given to the problem of bringing about a greater heat value per cubic foot of the limited firebox volume. Then by the direct means of higher boiler pressure, increased efficiency of evaporating surfaces, more perfect combustion, more uniform firebox temperature and steam pressure, improved circulation, feed water heated by gases and waste steam, higher superheat, systems of compounding in one or more cylinders to reduce back pressure, we will be able to place steam on a parity with electric operation.

In his address a year ago your president referred to the experimental work then being done in the use of pulverised fuel, in order not only to utilise the smaller sizes and lower grades of coal and lignite, but to ensure more even firebox temperatures, more uniform steam pressure, and to lessen the fireman's work on large locomotives. During the past year further applications of this method of stoking and burning solid fuels have been made, the Chicago and North-western Railway having equipped one of their existing superheated Atlantic type passenger locomotives which is now and has been for some time performing service between Chicago and Milwaukee on some of the fastest regular schedules in the world. The Delaware and Hudson Company have recently purchased, so equipped, a new consolidation locomotive which is one of the largest of that type. The Missouri Kansas and Texas Railway is now equipping a 10-wheel passenger locomotive for burning powdered fuel, and several other applications are in progress. Up to the present time various grades of bituminous coal, lignite, and a mixture of bituminous and anthracite coal have been used successfully in these experimental locomotives. The results obtained from the use of pulverised fuel in locomotive service may be briefly summarised: cinderless, sparkless, and smokeless operation; maintenance of maximum boiler pressure at all times without loss at the safety valves; increased boiler efficiency due to the high temperatures obtained; saving in fuel; the elimination of arduous labour on the part of the fireman and of delays and expense at the ash-pit. It seems now quite probable that the public demand for the elimination of the smoke, cinders, and sparks, the desirability of giving a value to what is now a waste product of mining, the growing scarcity of fuel oil, and the prohibitive cost of briquetting will, in combination with this method of increasing the effectiveness of steam boiler operation, afford as great an opportunity for lessening the cost of conducting steam railway transportation as has the use of superheated steam.

The improvement of old locomotives by the application of superheaters, brick arches, improved valve gear, and other modern apparatus, and even rebuilding with larger boilers and these appliances, is still going on. All these refinements, as well as the substitution of heavy new power and the retirement of old smaller locomotives has had, and will continue to exert, a marked influence toward the decreased cost of conducting transportation.

THE DIVISION OF THE PRODUCT OF INDUSTRY.*

BY SIR HUGH BELL, BART.

IN August, 1914, we prepared for a time of great distress. The Prince of Wales called on those whose means enabled them to respond to provide for the want which it was feared would overwhelm the mass of the people. There was a short period when it seemed this might arise, but as regards the greater part of the country this fear was of short duration. At once the enormous demand for various materials needed for the conduct of war stimulated all the industries connected with the production of metals and textiles; steel for guns and for shells, woollen goods for clothing, rose in price by leaps and bounds. Before long prices of food began also to rise, and the agricultural industry, which employs more hands than any other, began to share in the general prosperity. The rising price of food made it necessary to give additional wages to all classes of workpeople, and thus almost every class of the community benefited.

Men began at once to crowd to the colours, and in the great industries, at all events, allowances on a liberal scale were made to the dependants they had left behind. Soon the Government made grants on a scale more than once improved. The result of all this was to put the working classes of the country, or perhaps I ought to say their wives, into the position of being able to purchase to an extent to which in the past they had been quite unaccustomed, and so it happened that the war, far from producing distress, had to all appearances greatly added to the prosperity of the people of these islands. It cannot be said that all this took place quite smoothly. The economic machine, called upon for such unheard-of efforts, did grunt and groan as one in travail. There were labour disturbances more or less resembling those of the past. These appeared more menacing than usual because of the surrounding circumstances. But, though they were very alarming, they have never yet come to a very serious head. In these exceptional and undreamed-of conditions, I am more surprised that things should have gone so smoothly than that there should have been some hitches.

In trades with which I am most familiar I can affirm that the one object kept in view by both employers and employed has been to do the best for the welfare of the country as a whole; above all, to do nothing which would hinder the great object for which we were all striving—a satisfactory victory and a permanent peace. But we must not disguise from ourselves that not only are the problems which pressed for solution before the war began not disposed of, but that the conditions brought about by the war have rendered their solution more difficult.

Let us consider what has happened. Before the fateful August we in this country were disposing of an annual income which the best authorities have estimated to amount to perhaps as much as 2,400 millions sterling a year. At a bound we have almost doubled our expenditure. The demand for certain commodities has far outstripped the supply. All the energies of the nation have been applied to making good the deficiency. Those who produced munitions of war in the largest sense produced more than ever before; those who would by hook or by crook transform their factories so as to produce articles useful in war effected the transformation with something like the suddenness and smoothness of a scene in a fairy play. Those who had never conceived it possible that their machinery could be used for the purpose found means of altering it so that it, too, was turned to the use of the moment.

All this means that we are mortgaging our future prosperity, and that when the time of excitement and stress is over and the world becomes normal again we shall have to settle down to the dull occupation of meeting the interest on the debt we have accumulated. This will not make the solution to which we are looking forward easier. Rather will it demand much greater patience and forbearance than we have any of us shown in the past. It becomes all the more necessary to take heed now, lest when the time for action

* Abstract of paper read before the United Workers at the Prince's Skating Club, July 4th, 1916.

comes we find ourselves committed to remedies which, instead of alleviating, will only increase the evil. I confess I see signs of this being not unlikely. It would lead me too far away from my main thesis to elaborate this, but I may note in passing that methods which were formerly commended to us on certain grounds are now urged upon us as affording opportunities of pressing home our victories, and punishing our enemies while we derive untold advantage to ourselves and our Allies.

All these considerations lead me to the conclusion that just as before the war so now, even more urgently, are we called on to discuss the subject on which I have undertaken to address you—the division of the product of industry. Now, first of all, we must seek to establish what it is we have to divide. The total income of the kingdom is assumed by the statisticians to be something like 2,000 to 2,400 millions sterling, a huge figure of which none of us can, I think, form any conception. This vast sum is divided about equally between two very unequal bodies. On the one hand we have the whole of the industrial classes—all those who work with their hands—miners, metal-workers, agricultural labourers, and railway men, women and children in mill or workshop, all in receipt of weekly wages. If we include all those whose income is not above the standard of the classes I have just enumerated I think we are safe in saying that a full half of the total income is absorbed by these. There are between 15 and 20 millions of them, and with their wives and dependent children they comprise very much the greater part of the community.

What remains out of the 2,000 to 2,400 millions of money goes, on the other hand, to the small minority. It is stated that the 11,500 super-taxpayers take 145 millions among them. They may represent with their families 60,000 people, and thus form about a 750th part of the population to which goes about a 16th part of the income. It will be observed that the division I have roughly made is not by classes, but by amount of income. This does not vitiate my argument, for those whose income is below the income-tax limit are, in the main, those belonging to the class I have called industrial.

No one can pretend that this division is satisfactory. It cannot be well that a statesman should be justified in saying, even to make a rhetorical point, that 13 millions of the population of Great Britain are on the verge of starvation. In a certain sense the statement is true. But it is in a sense true of a much greater number of persons than those to whom Sir Henry Campbell-Bannerman referred. All those who depend for their income on what is somewhat ironically called earned income, in contradistinction to unearned income, are in this danger. When we come to examine the nature of the income of the minority we shall see this is so.

Let us proceed to do this by taking some examples. But first let us ask how this huge sum paid to the minority is made up. It comprises, in the first place, all the incomes derived from investments except so far as these fall under the total of £160 a year. Capital invested either in Great Britain or one of our Colonies, or abroad, goes to produce part of the unearned income. The railways, the ironworks, the cotton mills are all contributing. The owners of the ships which serve to bring food to keep Sir Henry's millions from starvation produce their share. The rents of lands and houses are there. All the public debt of this country, whether State or municipal, adds to the total.

But it also contains all rewards for services of all sorts when these rewards produce more than £160 a year. The great lawyer who earns his thousands is there—or the great doctor or surgeon. No one is compelled to contribute to their income. We go to them when we are in trouble, because we feel they possess a sort of skill for which in the circumstances no reward we can pay is excessive. As to the doctor or the surgeon, what is to be said against this argument, which I shall use in a somewhat different connection at a later stage?

To induce men to exert their greatest skill we offer large rewards. These rewards may take many forms and their relative attractiveness may vary from age to age and from country to country. That which for many centuries has proved the most attractive all over the world has been a reward in money. And so men have come to offer heavy fees for such services as those of which I speak. But to obtain the reward much practice is required, and so the great surgeon willingly gives a great part of his skill gratuitously. He begins, after a costly education lasting till perhaps his 23rd year, as house surgeon at a salary which keeps him still in the £160 limit. He gradually gets more experience and greater reputation till a rich man will readily pay hundreds of pounds for his help. But all the time he is doing hospital work for nothing. I do not undervalue the debt the community owes to him nor his unselfishness in spending himself, as he most generously does, but we must not overlook the fact that the skill he has acquired he thus maintains, and so is able to get from the wealthy the fees which raise him into the class of which the existence is frequently condemned. Yet let us not fail to observe that the unfortunate sufferer in the starvation class has got relief for nothing! This soul of goodness is found in things called evil. I don't say that money reward is the supreme, much less the sole, temptation to all men. I recall to your minds the anecdote told of Faraday, who in the height of his fame was asked by some capitalists to advise them in the prosecution of an enterprise calling for great scientific knowledge, offering a very large salary for his services. He is said to have replied that he was too busy to be troubled about earning money.

Or may I take another class? A successful dramatist or novelist receives to-day enormous sums for his work. The writers and composers of a popular musical comedy or revue net large amounts in royalties. Even more difficult is the case of the successful novelist. Such an one gets, say, £10,000 for a work of fiction. The book is sold cheaper than ever in the history of literature. The mere cheapness has permitted the large sales, and the royalty on the book produces the large reward I have mentioned. If the success is great enough it passes into a still cheaper form, and is sold by its 100,000 for 7d. or less a copy—each 100,000 adding perhaps another £500 or even £1,000 to the amount already paid. Who can with justice complain? Everybody engaged in the production of the book—papermaker, printer, binder, bookseller—gets good remuneration for their share in accordance with a scale settled by free negotiation, and the public is served better and more cheaply than ever before. Why should not the author have the full reward which remains after all these claims are satisfied? But for him none of the employment would have been forthcoming.

The minority amongst whom this huge share is divided comprises, however, many others besides those whom I have instanced, who stand for the persons for whose services the community is willing to pay, often as we have seen at what some may regard as exorbitant rates. But it comprises also all who serve at more reasonable figures. If we deducted the income falling to all these we should find that the amount paid to the remainder was not so extravagant as at first blush seems probable.

It is to a further examination of what remains that I wish to turn, for it is from this that many appear to hope to find some means of better adjusting the amount paid to various sections of the community. I propose to show that those who cherish this hope will be disappointed, for the fund from which alone relief can come bears no reasonable proportion to the sum needed to effect a considerable readjustment.

I have frequently cited my own experience derived from a life-long study of the economic conditions of my own trade. I will briefly repeat what I have said before. In the iron trade, beginning from the raw material (fuel, iron ore, and flux), and ending at the finished article, the proportion may be stated as follows: Out of every £100 spent, £70 to £75 goes to wages and salaries, of the £25 to £30 remaining about £10 goes to the owner of the works, and the rest is absorbed in various ways which it is difficult to state briefly. It comprises royalties paid for the minerals—it also comprises interest paid to others. This is an item on which I must dwell for a moment, because the more drastic reformers are for doing away with interest altogether. But how can I escape? The State and the municipality compel me to pay taxes and rates. A great part of these is labour, and is comprised in

the £70 to £75—but a great part is interest on borrowed money. What would the reformer have me do? If I don't pay I run the risk of imprisonment, and so I pay. Railway dues—of which more anon—consist largely of interest on capital. How can I escape paying this if I will have my goods carried?

In my trade in this country I turn my capital over roughly once a year, that is to say my gross income is about the same as my capital. It is clear, therefore, that the £10 or so left over for me is 10 per cent. on my own capital, while the £70 to £75 disbursed in wages directly or indirectly is 70 to 75 per cent. on my capital. If wages rise 10 per cent. I have to pay £7 to £7. 10s. more, and as the only fund in my control is the £10 aforesaid, it is clear very little will be left to me. My trade won't be worth carrying on. And all the more true is this because if I were to divide as profit the whole of the £10 remaining to me I should speedily become bankrupt because my works would become obsolete. If you will take the balance-sheets of any prosperous concern you will see that they never divide more than between one-half and two-thirds of the gross profits. The rest goes back to maintain and improve the business.

In other countries, America for example, the turnover is much slower. The magnates in New York were surprised at my statement and told me that three years was more like the time needed in their American steel trade. That means that the capital is much larger than in England, and this quite agrees with the opinion formed on other evidence. For example, the horse-power per worker in the United States is said to be 2,346 against 1,182 in this country. I cannot now pause to draw attention to all that is comprised in the contrast, which has, however, a great and very direct bearing on my subject. I will rather devote the time which I still have at my disposal to giving you some figures with reference to a very important branch of industry in this country which turns its capital over with surprising slowness.

The railways of Great Britain have a capital of £1,341,222,000. Their gross receipts in 1914 were £139,098,000. Their capital was turned over in about nine years. The surplus income after meeting all costs of working, but before paying any dividend, was £30,925,000. They had over 22 per cent. against my 10 per cent. Now it might be thought that out of this large surplus it would not be found difficult to find something to rectify the wide discrepancy between the shares of the majority and the minority. Yet observe that on the capital embarked in railway enterprise in Great Britain an average dividend of just over 2½ per cent. was earned.

If it is objected that I cannot fairly take the whole railway system of Great Britain as an example, I will ask you to consider with me the figures of one very prosperous railway, of which I am a director. I take the figures of the year 1913, before the war disturbed everything. At that date the capital invested in the undertaking amounted, in round figures, to 85 million pounds. The gross income was 12½ millions, the expenditure 8 millions, and there was a balance of 4½ millions. The capital was, as you see, turned over in something under seven years. There would have been needed 4¼ millions to pay 5 per cent. on the total capital spent. The wages paid in that year came to 4⅓ millions, and were distributed among nearly 53,000 persons of various sorts; each on the average thus received a little over £80. 10s. in the year.

But here I must make that further subdivision of which I spoke at an earlier period. The 53,000 men employed consist not only of those belonging to the operative class—those whose income, on the whole, may be taken to fall below the income-tax level, but also, first, the clerical staff, next, all those concerned with administration, and finally those to whom the superior control of the company's affairs is entrusted. Taken altogether this constitutes a great number of persons. In fact, there are upwards of 8,000 of them. Very much the greater part occupy subordinate positions and receive relatively small pay. I will not be tempted into a digression on the subject of their pay, which is full of interest and beset with difficulties. They occupy an important position in the railway hierarchy and constitute in some sort the subordinate nerves by which the central brain, of which I am about to speak, communicates with the periphery.

I now come to the real motive force of the undertaking which, to continue my simile, may be compared to the great ganglia and brain of the higher living organisms. To this small group of persons, barely ⅛ per cent. of the whole army of the 53,000 persons, is confined all the important duties of general direction and superior management. It is sometimes said that the product of industry is given in too large a proportion to the highly paid officials. Let us see how this stands in the case of the railway company. The total amount payable to the higher members of the staff—the ganglia and brain—does not amount to £100,000 out of a total income of 12¼ millions, in fact much less than ⅔ per cent., while the whole salaried staff does not absorb 7 per cent. of that total. I have usually given this figure as not exceeding 5 per cent. It is greater in the railway service because certain grades are counted as clerical which in ordinary industry are called operative. On a true comparison made on precisely the same lines I incline to the belief that 5 per cent. would cover both sorts of industry.

The whole complex of nerves, ganglia, and brain absorb nearly a million of money, but as the average income of each individual is only a little more than 40s. a week it is evident not much can come from this source towards the improvement of the position of the less important but more numerous elements of the organism. If I deduct the earnings and the numbers of these three classes I find that the operatives pure and simple earn on the average £76 apiece a year.

Before I leave this subject I would like to call special attention to the small amount paid for superior management and the small number of persons in this class. That great skill is needed for this work cannot be questioned by anyone conversant with the matter. A competent manager is very hard to find, and must be found among the small group of officials at the top numbering considerably less than 100 all told. Is this enough to give width of choice to the employer and chance of being chosen to the man who has the root of the matter in him? A general manager may not unfittingly be compared with the great specialists in some of the walks of life to which I have referred before. I am comforted by the reflection that the North-eastern Railway has supplied out of its score or so of men who occupy the brain pan of the company not less than three officials to the country in its present straits. I hope this may be taken to show that we have succeeded within our own compass, and without going outside the subjects of the King, in gathering round us a group of very competent men. From all this I hope I have made it clear that no serious improvement in the remuneration of the great mass of railway men can be got from any of the three classes into which I have divided the salaried staff.

On one other point I should like to touch before I proceed. I have been told by railway men that we have too many foremen. To that I make reply that the men have themselves to thank. Foremen and inspectors and such like are employed because experience has unfortunately made it clear that men must be watched or they will not do their work properly. The employer dislikes all expenditure with which he can dispense, and the workmen may rely on it that all such supervision would vanish as soon as it was found to be unnecessary.

The dividends were distributed among 60,670 holders of shares and debentures, so if the whole surplus of 4½ millions had gone equally each shareholder would have got a trifle under £73. 10s. It will be seen that if the men of all sorts got 10 per cent. more, the shareholders would have had to sacrifice about 11 per cent. of their income. But note the curious coincidence that each shareholder is responsible for the employment of rather better than one man, the proportion between 60 and 53, say (to be nearly accurate) twelve-elevenths of a man. Now take an average shareholder who has something like £1,600 invested in the North-eastern Railway Company. It may be the delicate orphan daughter or widow of a man who by strenuous labour succeeded in accumulating £1,600 to keep his family from want and who died

when he had got thus far. The pitiful £73 (less than 30s. a week) is to be diminished to £65 in order that men whose standard of life is fulfilled with £80—or if I exclude the salaried classes £76—shall have more pay.

But there is a further reason which belongs to the region not of sentiment like the foregoing but of hard economics. In a growing district like the north-east of England the railway is perpetually called on to give additional and greater facilities. Careful consideration has led to the conclusion that an annual capital expenditure somewhere in the region of £1,000,000 is required for this purpose. Call it 1 per cent. on the actual capital and you see another coincidence worth noting—the growth of the population corresponds with the call made on the railway for additional accommodation. The subject is one which occupies a great deal of the attention of railway directors, for it means more capital, and capital must be tempted. How difficult it has been in recent years before the war to get these additional resources all who are familiar with railway finance will know. The difficulties have frequently compelled the delay of works which otherwise would have been put in hand. If the return to be obtained on the investment is reduced, the difficulty to which I refer will be increased, the growth of the district will be checked, employment will fall off, and wages instead of rising will decline.

I hope it will be recognised that the same difficulty which occurs in the iron trade also presents itself here, and in this case is applicable to an industry which employs capital comparable to the whole value of the agricultural land of the country.

Now the moral of all this long discourse is that under existing circumstances the present division of the products of industry cannot be divided in any very much different way from the present. The examination which I made of my own industry, with an annual turnover of the capital engaged, gives the same results as that we have just considered in greater detail for the very different transportation business. If you consult the exhaustive examination undertaken by the Census of Production of 1907, of which the report was published in 1912, you will find the same result is reached.

It would be a vain and impotent deduction if we were obliged to admit that, bad as we agree the present division to be, nothing better could be expected in the future. Fortunately, this is not the conclusion which is forced upon us. In passing I have indicated both from what source the improvement in the condition of the mass of the people has come in the past and whence, as I believe, it must come in the future. When I first had to do with wages, common labour was getting something like 2s. 6d. a day. In the old records of my firm I find figures below 2s., proving that 50 and more years ago the improvement had begun. It has risen till, as we have seen, the average wage of all persons, young and old, skilled and unskilled, stands at the 5s. a day for which, in the great coal strike in 1912, the miners clamoured as the minimum.

How has this been accomplished? By perpetually improving the appliances put into the workmen's hands. I can give a striking illustration. When I began to make pig iron the cost of labour at the furnace was about 6s. a ton. Before the war it was a little over 3s. a ton. Yet every man was paid wages which in malt and meal were fully twice as high as 50 years since. These improved conditions had been brought about in spite of persistent resistance by the men. Each improvement was suspected as a means of reducing the number of men, while in fact it would, in the long run, have just the contrary effect.

The problem which faces us now with menacing urgency is to bring these facts home to all engaged in industry, to all who hope the new world on which we have entered is to be a better world. One hopeful sign is that all have learned how much more could be accomplished under the stress of national emergency and the spur of patriotic sentiment. The women have shown that the so-called skilled man in the shop possessed only such skill as a willing hand and brain could attain in a few weeks. It may be Utopian to hope that the baleful shop rules of the past, suspended for the period of the war, may never return. It will need great tact and self-denial on both sides to effect this, but were it possible to accomplish it how different would be the division of the product of industry. If the men instead of opposing the employment of additional power demanded it, if in place of seeking to restrict the output they sought to increase it, and instead of refusing to "mind" more than one machine they insisted on "minding" many, if, in a word, the 1,100 h.p. per man in this country could grow to anything like the 2,300 of America, wages would rise here as they have risen in America.

See how the thing works. Let me go back to my iron illustration. The concern has 100 as its capital (it may be pounds, or thousands of pounds, or millions—you have just to add so many more noughts). Its gross income is 100; it gives its men 75 per cent., keeps 10 per cent., and uses the remainder in the ways described. It doubles its capital and output, but does not increase the number of its men; 20 goes as before to the capitalist, 30 as before to satisfy all other claims, and the men get 150 to pay their wages—the £73 of the workman has become £146. It is not so simple as this in fact, but the principle is the same. And it is in this way that the improvement has been effected in the past.

We have seen that the gross income of the kingdom is divided into two halves, falling to two classes differing very greatly in number. Of the part falling to the minority we have seen reasons to doubt whether we could attack any considerable fraction with any hope of success on either economic or ethical grounds. As to all that fraction that goes to reward capital applied to industrial enterprise, great or small, we have seen that compared with the revenue it produces so small a portion falls to capital, that even if it were all taken no great increase would be awarded to labour. And, as it appears to me, we are driven to the conclusion that it is not in this way that we can obtain that improvement in the standard of life of the mass of the people which we all desire to see effected. But I suggest that this improvement is within reach of those in whose favour it is to be made if they, and those who employ them, will frankly and loyally co-operate to effect the necessary change.

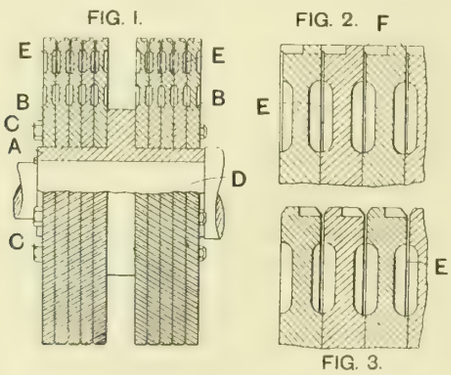
I will conclude this too long address with an anecdote which I told recently in another place, and which, to my mind, illustrates the whole problem. A workman I know said, "I can earn all I want in three days, so I never fash myself to work longer. I enjoy three days' leisure and I leave a job for another man." That he should work three days and waste three (if he did waste them) was his own affair. He was a bad citizen, but in a free country he was within his right. But he was quite wrong about the job for another man. For if he had worked he would have earned money; if he had earned money he would have spent it; if he spent it he must have employed labour, for labour, as we have seen, is the chief ingredient in all production. But if he had said, "I find by long experience that in three days, working as hard as I know how, I can produce as much as if I worked six—and so I do all I know for three and then rest and enjoy life for three, while my mate Jack, who is just such another as I, takes my place. The two of us have three days' leisure in each week and the world is no worse off" then no fault can be found. If all men and all women in all ranks of life would act like my hypothetical Jack and his mate, the problem of the division of the product of industry would be solved.

METHOD OF MANUFACTURING ELASTIC HELICAL GEARS.

A METHOD of manufacturing elastic helical gears of the type which comprises a plurality of discs or laminæ fixed on a common support or shaft, and slightly spaced apart at their peripheries to permit of axial yielding under tooth pressure, has recently been patented by the General Electric Company, of Schenectady, New York. The teeth on these gears must necessarily be formed after the plates have been assembled in order to ensure that they are correct. It is not possible, however, to cut the teeth on the discs with the peripheral portions spaced apart, as they would yield and vibrate under the pressure of the cutting tool to such an extent that the teeth would not be true. On the other hand it is not possible to cut away

the material from between the discs to form the space after the blank has been assembled, as the width of the space is so slight as compared to its depth that a suitable tool could not be constructed to perform the work. For example, the width of this space in ordinary practice may be only about ·01in. Furthermore, it would not be desirable to disassemble the gear after the teeth have been cut in order to remove the desired material, owing to the difficulties of reassembling the discs again in exact relative position.

In the method under notice the teeth are cut on what is substantially a solid blank. All the material which is to be removed from between the respective discs, with the exception of the outer peripheral portion thereof, is removed before the discs are assembled. The discs are then assembled in the desired manner and clamped firmly together at their central portions. The teeth are then cut on the face of the blank, after which the remainder of the material, which is to be removed for forming the space between the discs, is cut away by a suitable tool. As it is located at the outer edge of the discs it is easily removed. Fig. 1 is a side view partly in section illustrating a completed gear. Fig. 2 is a detailed sectional view illustrating an intermediate step in the method, and Fig. 3 is a similar view showing the completed gear. Referring to the drawing Fig. 1, A indicates a support upon which are mounted the discs or laminæ B firmly clamped and



ELASTIC HELICAL GEARS

held together by the bolts C. The support is carried by a shaft D. This figure shows a completed gear, and it will be noticed that the discs or laminæ are spaced slightly apart at their peripheries, as indicated at E. It will be seen that this space is of considerable radial depth as compared to its width. The width of the spaces between the discs is considerably exaggerated in the drawing for the sake of illustration.

In constructing the gear the discs or laminæ are machined to the proper thickness, and all of the material for forming the space between the outer periphery of the discs is removed, with the exception of the outer portion, as indicated at F in Fig. 2. The space is formed by removing all the material from the side of one of two adjacent discs. The discs or laminæ are then assembled and fixed on their support, and when so assembled have the general appearance shown in Fig. 2, with the exception that there would be no teeth on them. After being assembled, the blank is finished to size and the helical teeth cut thereon. The material F which is left between the discs serves to back up the discs so that there can be no vibration, and the teeth can be readily cut on an ordinary gear-cutting machine. The cutting of the teeth removes a portion of the material F, as will be obvious, *i.e.*, the portion between the teeth. After the teeth have been cut the gear is placed in a lathe, and the remainder of the material F is removed by cutting a V-shaped annular notch between each two discs. This gives a completed structure, as shown in Fig. 3.

OIL VERSUS WATER FOR QUENCHING FORGINGS.*

BY C. D. YOUNG.

THE investigation discussed in this article was made in order to show the difference between the physical properties of a large forging quenched in water and those of a similar forging quenched in oil. The results obtained indicate that there is an advantage in the use of water as a quenching medium, as might be expected from its physical properties. Results obtained at a large heat-treating plant, which has turned out thousands of tons of quenched-and-tempered carbon steel, indicated that no disastrous effects on the forgings are to be anticipated from the use of water as a quenching medium, providing proper care is taken in the handling of the steel throughout the process. The forgings used for this experiment consisted of two 10in. locomotive driving axles having a centre bore 2in. diam. extending the entire length. Both axles were from the same melt of steel, and preliminary chemical analysis indicated the same chemical composition. One axle was treated at the Juniata shops of the Pennsylvania Railroad Company, by water quenching, and the other axle by a steel company which makes a practice of oil quenching.

The axle marked W was heated to 1,550° Fah., and at that temperature quenched in water at about 60° Fah. Then, in a furnace maintained at 1,175° Fah., it was heated to that temperature and cooled therefrom in the air on a dry ground floor. That is, this axle, after being quenched from 1,550° Fah. in water at about 60° Fah. was "drawn" to a temperature of 1,175° Fah.

Similarly, the axle marked O was quenched in a heavy oil from the same temperature (1,550° Fah.), and drawn in a furnace to 1,200° Fah., the cooling being done in the air the same as for the water-quenched axle.

It was aimed to have the tension tests on both axles show an elongation in 2in. of about 22 per cent. After treatment, the axles were laid off for cutting up into tension test specimens, as shown in Fig. 1. It will be noted, in effect, that out of each axle there were cut—axially and for the full length, 120° apart—three radial and straight slabs of the overall thickness of a test specimen, and out of each slab five 6in. lengths, each identified as to its original location in the axle, whether cut from the end and from which end, or whether from the centre, or from midway between centre and end, and from which slab; and then each 6in. length was cut lengthwise into three specimens and their location further identified as to whether cut from the inner or outer circumference or from the middle of the wall.

As shown in Fig. 1, the identification marks for the five 6in. lengths, in order from one end, are, respectively, A, B, C, D, and E. It is also shown that the specimens from length A, for example are numbered radially from the outside of the axle towards the axis, the three specimens from the first slab being numbered, as described, 1, 2, 3 throughout; second slab 4, 5, 6; third slab 7, 8, 9, respectively. The specimens from lengths B, C, D, and E also have the same numbering as those of length A.

As already explained, the letter W applies only to the water-quenched axle and O only to the oil-quenched. For example, the markings WC2, WC5, and WC8 each apply to a different slab, but all refer to specimens cut from the water-quenched axle, from its central 6in. length, and from the middle of the wall. The corresponding specimens for the oil-quenched axle are OC2, OC5, and OC8. Altogether there were 45 specimens per axle, 15 specimens from the three longitudinal planes through the axle, and nine specimens from all three slabs from each of the five 6in. lengths. The test specimens were turned up to the standard 2in. gauge length, ½in. diam. The elastic limit was determined by means of a strain gauge. All tests were conducted on the same 100,000-pound tension testing machine, using a machine speed of ⅛in. per minute for both the elastic limit and the tensile strength.

Results of the tension tests in which comparison is made with repect to the distance of the test specimens from the axis of the axle, and in which comparison is made with respect to the location of the test specimens along the length of the axle are summarised in Table I, in which it is shown that the average results are more nearly uniform with respect to the length of the axle than with respect to distance from the axis. This is probably due to segregation, and it was found by chemical analysis that the carbon content was not uniform throughout the section. Segregation is perhaps to be expected in the ordinary output of commercial forgings, but not to the extent found here.

A comparison of the average physical properties of all test specimens from both axles (Table I) shows that with an elon-

* Read at 19th annual meeting of the American Society for Testing Materials, Atlantic City, N.J., June 27th to 30th, 1916.

gation 4·5 per cent. less than that of the oil quenched axle resulting from the difference in treatment, the water quenched axle gave an elastic limit 6·6 per cent. greater, about the same tensile strength, and nearly the same reduction of area.

TABLE I. *Summary of Results of Tests.*

LOCATION FROM END.

Location from End	Specimen Marks. Water Quenched	Specimen Marks. Oil Quenched	Elastic Limit, lbs. per square inch. Water Quenched	Elastic Limit, lbs. per square inch. Oil Quenched	Tensile Strength lbs. per square inch. Water Quenched	Tensile Strength lbs. per square inch. Oil Quenched	Elongation in 2in. per cent. Water Quenched	Elongation in 2in. per cent. Oil Quenched	Reduction of Area, per cent. Water Quenched	Reduction of Area, per cent. Oil Quenched
OL	*WA*	*OA*	54,857	51,250	97,111	97,650	22·1	23·2	39·9	41·9
L 4	*WB*	*OB*	52,634	52,160	96,637	97,304	22·8	25·2	40·3	45·7
L 2	*WC*	*OC*	55,626	51,230	96,472	96,880	23·7	25·1	44·0	46·8
3L 4	*WD*	*OD*	56,064	51,170	96,470	96,030	23·1	23·5	42 5	40·7
1	*WE*	*OE*	53,376	49,780	95,720	94,210	23·6	24·0	44·3	41·7
Average	.....	.....	54,509	51,118	96,482	96,415	23·1	24·2	42·2	43·4

LOCATION FROM CENTRE.

Axis.										
R − ½in.	*W* 1, 4, 7	*O* 1, 4, 7	55,216	51,423	94,187	93,719	25·6	26·0	52·7	49·7
$\frac{R+r}{2}$	*W* 2, 5, 8	*O* 2, 5, 8	51,064	48,390	95,508	92,572	24·4	25·5	44·5	45·8
r + ½in.	*W* 3, 6, 9	*O* 3, 6, 9	57,255	53,543	99,751	102,962	19·2	21·2	29·7	34·5
$\frac{R+r}{2}$	Minimum permitted by A. S. T. M. Specifications.		50,000		80,000		20·0		40·0	

This table gives the average results from all test specimens located equidistant from the axis in each axle. The average results from the outer test specimens at the location R − ½in. show the water-quenched axle to have about the same elongation as the oil-quenched axle, 7 per cent. greater elastic limit, 5 per cent. greater tensile strength, and 6 per cent. greater reduction of area.

The test specimens from the middle of the wall show lower elastic limit and tensile strength than either the outer or inner test specimens, except that the strength of the water-quenched axle at the middle of the wall was found to be somewhat higher than in the outer specimens. It is evident that this mid-region of the section was less affected by the heat treatment. The water-quenched axle, however, shows higher elastic limit and tensile strength in this region than the oil-quenched axle, although, as already stated, the average strength of the entire section came out very closely the same for both.

The results obtained from test specimens from the inner surface of the wall are not so consistent; that is, they show a higher elastic limit and a lower tensile strength, elongation and reduction of area for the water-quenched axle.

All of the forgings tested meet the requirements of the specifications of the society, except that the elastic limit found in the middle of the wall in the oil-quenched axle is somewhat low.

Photomicrographs taken from test specimens WE6 and WD3 on the water quenched axle do not afford any apparent explanation for the difference in physical properties, but in both cases indicate that the water quenching was effective in securing a good diffusion of the carbon throughout the structure, leaving only a small amount of ferrite network. The carbon content in these two specimens was about the same slightly over 0·60 per cent.

The same is true of photomicrographs taken from test specimens OE4 and OD9 of the oil quenched axle, the latter having shown higher elastic limit and tensile strength, with lower elongation, no explanation being apparent from the microstructure, except that specimen OE4 indicates a lower carbon content, which was confirmed by chemical analysis. The carbon content in specimens OE4 and OD9 was 0·52 and 0·62 respectively. The structure of the oil-quenched axle shows a fine network which is absent from the water-quenched structure, although characteristic of carbon steel treated by the oil-quenching method. Table II gives the chemical analysis of representative test specimens taken from each axle. The water-quenched axle samples, taken from the A end, show that the outside and midway specimens WA4 and WA5 have the same carbon content, but when compared with analysis from specimen WA6 of the inner wall there appears a segregation of 15 per cent. The same is true of the samples taken from the opposite end of this axle.

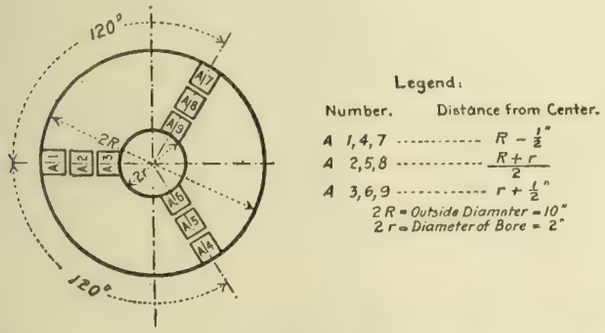
In the oil-quenched axle, also, the same segregated condition is present, the outer and middle test specimens having about the same carbon content, while the specimens OA6 and OE6 taken close to the inner surface, show a segregation of 14·5 and 11 per cent. respectively, when compared with the corresponding samples taken from the middle of the wall.

The segregation found in both of these axles indicates a condition which increases the difficulty of securing a satisfactory treatment of the forgings, and points to the desirability of including in all specifications for forgings which are to be heat treated, a clause to govern the allowable amount of segregation; otherwise it may be expected that extreme segregation will be found, as in the forgings here discussed.

TABLE II. *Chemical Composition of Specimens.*

Specimen Marks.	Carbon, per cent.	Manganese, per cent.	Phosphorus, per cent.	Sulphur, per cent.	Silicon, per cent.
WA 4	0·53	0·56	0·019	0·031	0·159
WA 5	0·53	0·56	0·018	0·030	—
WA 6	0·61	0·58	0·019	0·039	0·158
WE 4	0·53	0·56	0·019	0·030	0·162
WE 5	0·53	0·56	0·019	0·032	—
WE 6	0·61	0·57	0·025	0·040	0·299
WD 3	0·62	0·57	0·023	0·042	0·176
OA 4	0·55	0·56	0·018	0·030	—
OA 5	0·55	0·57	0·018	0·033	0·190
OA 6	0·63	0·59	0·019	0·041	0·195
OE 4	0·52	0·55	0·021	0·036	0·167
OE 5	0·54	0·56	0·019	0·031	0·182
OE 6	0·60	0·59	0·019	0·038	—
OD 9	0·62	0·57	0·020	0·044	0·176

WA is water quenched; *OA* is oil quenched.



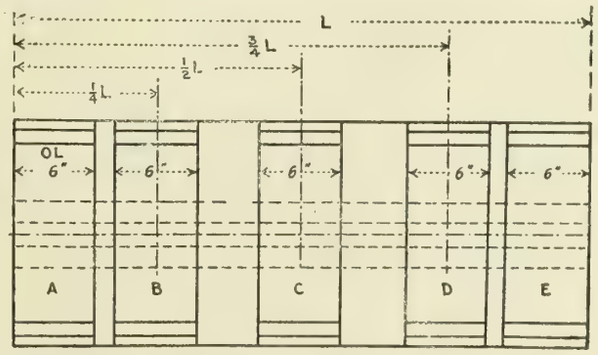


FIG. 1. LOCATION OF TEST BARS FROM HEAT-TREATED AXLES

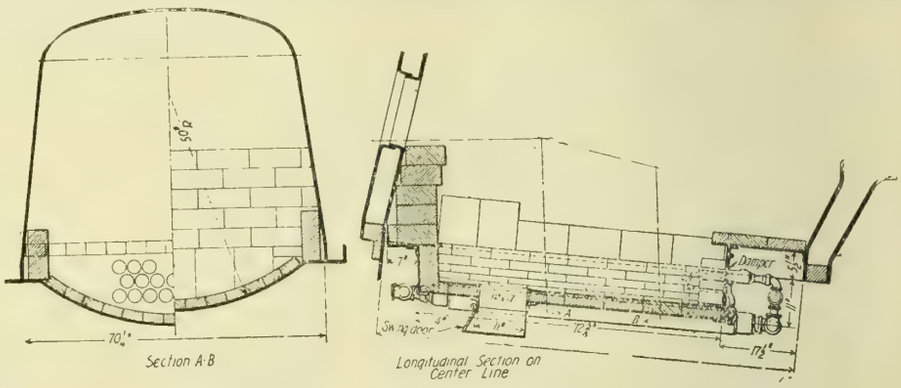
MISFITS IN SCREW THREADS.

IN the course of a paper on "The Standardisation of Screw Threads," presented before the convention of the American Railway Master Mechanics Association, Mr. F. O. Wells stated that in searching for the principal reasons of misfits in screw threads over a period of years, it had been found that non-interchangeability was not so much due to inaccuracy in the screw-cutting tools themselves as to the unreliable methods employed in taking and transferring measurements, and also to the total disregard of proper tolerances for both male and female threads. In theory screw-cutting tools should reproduce their own threads: in practice they did not always, on account of the conditions, all of which could be controlled if one wished to do so. Therefore, the principal point to be brought forward was that it was not the tools that had to interchange, but the work done by them. It was generally agreed among the tap-and-die and screw manufacturers that the screw was the basic from which all formulas and calculations should be derived. The usual custom was to tap a hole and fit the screw to the tapped hole, and in the process of making a screw, if the lead of the tap was not normal which had been used to tap the hole, the operator kept cutting down the screw to fit the hole, and consequently got it greatly under size before it fitted. Therefore, the operator did not get a proper bearing on the angle of the thread, because in all probability there were but one or two threads bearing on the sides of the tapped hole. It was a fact that the vast majority of taps broke in use and that very few wore out. Some authorities put the total breakage at 90 per cent. of all the taps used. This breakage was due largely to the fact that the holes to be tapped were not either drilled or reamed to a large enough size. For ordinary work three-quarter depth of thread was good practice. A nut having only one-half depth of thread would break the bolt before it would strip the threads. The outside diameter had little or nothing to do with the fit for a screw thread as long as the screw was made basic, or smaller, and the tap over basic. If this condition existed, when put into use the metal in the top of such threads flowed and made a fit depending upon the tolerances; the closer the tolerances, the tighter the fit. Pitch diameter and lead were two factors of equal and reciprocal importance. To obtain true working standards, these factors must have close attention on the part of the designing engineer. It had been found, after a long series of tests, that long, curly chips from taps required less power, and there was consequently less breakage than from taps which made fine, granulated chips. This statement was equally true of dies. To obtain these curly chips it had been found necessary to give these taps and dies a certain amount of positive rake, this rake depending upon the material to be cut. One would not think of using the same lathe tool or milling cutter for cutting all kinds of material, and the same condition existed with taps and dies. On every car and engine there were many screws and nuts subject to constant jar and pound. To make the tolerance of screw threads within well-defined limits for railroad work would tend to prevent the nuts and screws from working loose, and no doubt help to decrease the number of accidents that could be prevented by some forethought and care. These limits must be very carefully worked out, because on screw threads subject to jar, if the fit was too loose, the parts would quickly come apart, while if the fit was too tight the strain set up by the tight fit, together with the jar, would soon carry the part beyond its breaking strength, and so cause a rupture.

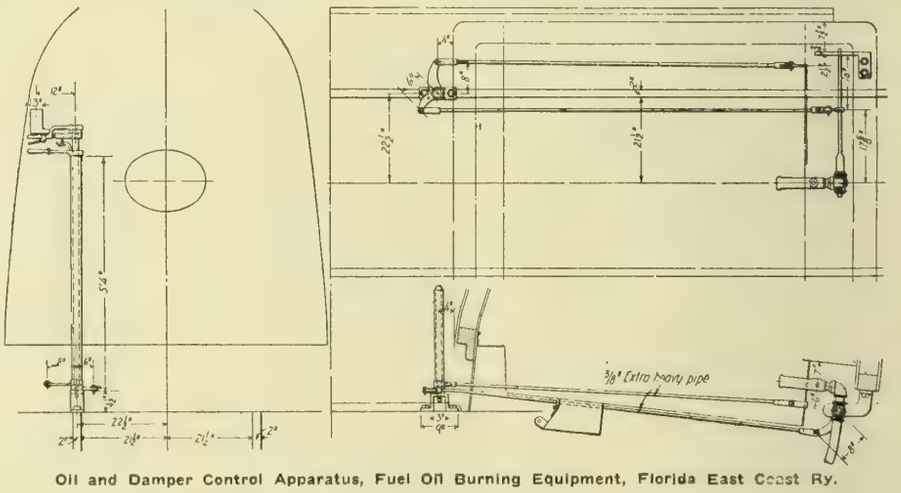
OIL-BURNING EQUIPMENT FOR LOCOMOTIVES.

AFTER considerable preliminary experience, involving the conversion of some 25 engines from coal to oil burners, the Florida East Coast Railway has decided to use oil as fuel on all of its locomotives operating between Key West and Jacksonville. The general arrangement of the oil-burning equipment of these locomotives is shown in the accompanying illustrations, for which, along with the following description, we are indebted to our American contemporary "The Railway Review."

The locomotive equipment used is characteristic of that employed on other large systems which have gone extensively into the use of oil as fuel. Thus, the oil tanks are made to fit into the coal space of the tenders as originally constructed, and are provided with heater coils and water drain valves, &c. The main tank heater consists of a coil of galvanised iron pipe placed over and surrounding the flow of the fuel from the main body of oil through the outlet valve. This serves to keep the oil in a freely fluid state. The steam supply for this heater is received through a flexible jointed pipe from a special turret on the locomotive boiler head, with the control valve placed within easy reach of the fireman. A drain from the heater coil serves to carry off condensation. From the main outlet valve in the tender the oil flows through a flexible metallic conduit by gravity through a superheater, consisting of a steam-jacketed length of pipe, through the oil flow control cock and thence to the burner.



Fire Pan and Arrangement of Brick Work, Fuel Oil Burning Equipment, Florida East Coast Ry.



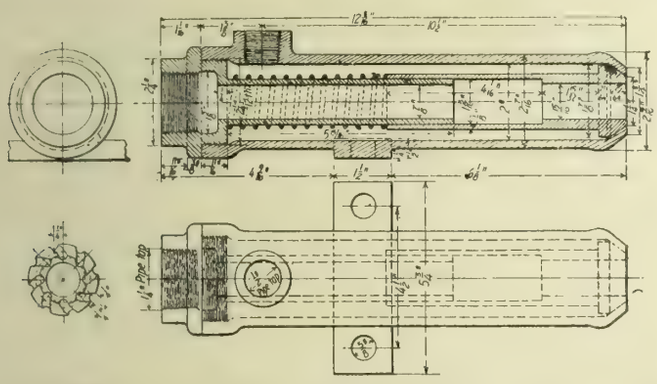
Oil and Damper Control Apparatus, Fuel Oil Burning Equipment, Florida East Coast Ry.

The burner, which is of the Clarke variety, shown in cross-section in one of the illustrations herewith, is placed in the forward end of the firebox. The arrangement of this burner is such that the flow of oil constitutes a core which is completely surrounded by the atomising steam. The steam thus serves to further heat and thin the oil. As it escapes from the circular nozzle it passes through a series of spiral flutes in such a way as to give the oil a vigorous, swirling action, completely diffusing it with the atomising steam. The oil nozzle is telescopic, the movable portion being held in position against the conical aperture through which the steam escapes by means of a spring. Increased pressure of

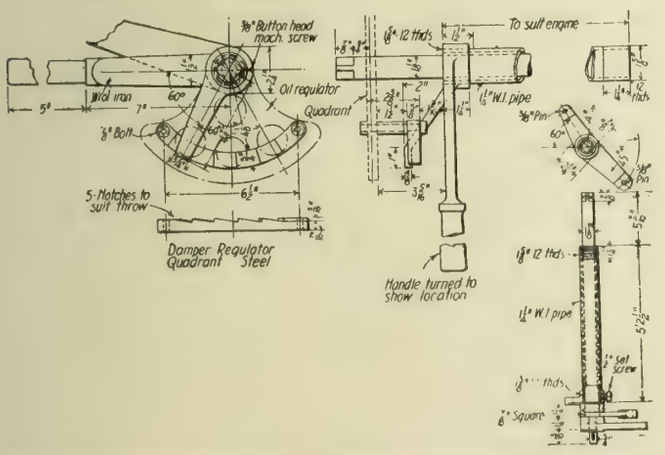
steam re-acts against the force of this spring and allows itself a greater area of opening through which to make its escape. The quantity of oil permitted to flow to the burner is controlled by means of a special feed cock in the oil pipe line just ahead of the burner, the operating lever therefore being mounted, together with the damper control regulating lever, on a stand within easy reach of the fireman's seat. The steam with which to atomise the oil, as in the case of that for the tank heater, is received from the special turret, its control also being placed convenient to the fireman's side of the cab.

The fire pans are of the round bottom variety, sloping from back to front in such way that whatever surplus of oil there may accumulate in the pan is drained out at the forward end and does not bring about danger from explosion. The bottoms of the pans are lined with firebrick, in addition to which a flash wall is built up across the back end of the firebox to the height of the door. A course of brick is set on edge along the sides of the fire pan to protect the lower portions of the side sheets from the intense heat and at the same time to assist in sealing the pan at the point of its attachment to the mud ring.

Very particular attention has been given the matter of draughting. In order that a proper atmospheric balance may



The Clarke Fuel Oil Burner, Type Employed on the Florida East Coast Ry.



Front Damper Regulator, Fuel Oil Burning Equipment, Florida East Coast Ry.

be maintained within the firebox, air is admitted at two points, these being through a damper at the front wall of the fire pan, covering apertures through this wall at either side of and beneath the burner, and through a second damper controlling the supply through the flash hole located about two-thirds of the distance from the burner back to the rear of the pan. The perforations in the front wall of the fire pan covered by the first mentioned damper have inserted into each a 4in. length of tubing. Air supply for combustion is received at this point during the operation of firing-up. After steam has been raised and the engine starts working, this damper may be partly or entirely closed, and further air for combustion may be received through the second damper at the flash hole. This latter damper is manipulated by means of a notched lever set in the floor of the cab. In the front end of the locomotive is provided a short nozzle and a long draught pipe. A quick opening blower valve of the Okadee variety is installed to facilitate the manipulation of the fire when the engine is not working.

The fireman, in stoking these engines equipped for oil burning, has at his command front and rear damper levers, the oil control lever, and four steam valves. The first of these latter regulates the flow of steam through the flexible pipe connection to the heating oil in the tender, the second supplies steam for the atomisation of the oil at the burner, the third controls the supply of steam to the oil superheater, and the fourth is provided for the purpose of blowing steam through the oil conduit from a point at the forward end of the superheater, back through that element and the flexible pipe connection to the tender. The occasion for this arises when for any reason the oil conduit becomes stopped up. At such times the oil feed cock, located between the forward end of the superheater and the burner, is closed. This arrangement is useful also in providing a preliminary means of thoroughly agitating and heating the oil in the tank prior to firing-up.

MODERNISING OF EXISTING LOCOMOTIVES.

A COMMITTEE, with Mr. F. J. Cole as chairman, presented a report at the recent annual convention of the American Railway Master Mechanics' Association with respect to the following subjects: (1) Length of time an engine should be built in order to justify modernising; (2) the conversion of consolidation engines into Mikados; (3) change of type of engines; (4) superheating saturated-steam engines; (5) brick arches; (6) outside valve gear; (7) size of valves. A circular was sent to the members of the association, enquiring as to the character, extent, and results of their practice in the modernising existing locomotives, and from the 32 replies received, the committee arrived at the following conclusions:—

Length of Time an Engine Should be Built in Order to Justify Modernising.—In this question the matter of what constitutes modernising should be clearly borne in mind. Old engines are usually lighter in weight and have less tractive power than those built at present. The track, bridges, &c., have been increased in strength on most railroads, so that higher axle loads and greater total weights can be borne with safety than in previous years. In many instances, however, the capacity, weight, and condition of old engines would justify the application of many improvements, such as superheating, &c., which make for economy and increase in capacity.

When consideration is given to the question of changing the type of engines, as for instance, changing the wheel arrangement of consolidation (2—8—0) into Mikado (2—8—2), the matter of weight and capacity is the vital issue. Will the engine, after a large amount of money, say 50 per cent. of its cost, has been spent, be modern in all respects, and will it perform the work in the most satisfactory and economical manner? In other words, will it, when rebuilt, be a thoroughly up-to-date engine as could be purchased for this particular service? The matter, therefore, resolves itself into one of judgment as to how much should be spent upon an old engine, and whether the old engine after being rebuilt or modernised is a thoroughly satisfactory one for the service which it is intended to perform.

The Conversion of Consolidation Engines into Mikados.—A great many locomotives have been thus modernised. This change is especially desirable where greater boiler capacity is necessary in maintaining speed and sustained horse-power in cases where the limitation of the engine has been the inability of the boiler to supply the necessary amount of steam. Where consolidation engines are of large size, with wheels of suitable diameter and ample crank pins and axles, having modern tenders of large capacity, where many other parts can be used to advantage, it is often economy to reconstruct such consolidations (2—8—0) and convert them into Mikados (2—8—2). One leading railroad system has converted between 400 and 500 consolidations (2—8—0) class into Mikados (2—8—2) class. The efficiency of its power is thereby materially increased.

Most consolidations built during the last ten or fifteen years have shallow fireboxes on top of the rear pair of drivers. It is more difficult with such engines, on account of the shallow throat, to equip them in a satisfactory manner with brick

arches. When they are converted into Mikados, a firebox of any size and depth can be used and brick arches applied in a most satisfactory manner. Flues may be increased in length and smoke-box temperatures, that is, the heat of the escaping gases, may be decreased correspondingly. The longer boilers also permit the use of combustion chambers, if desired. A Mikado engine can at times be operated at much longer cut-off without lowering the steam pressure too much, the boiler being ample to provide an adequate amount of steam under the most exacting conditions.

As a general proposition, a locomotive boiler cannot be made too large. It often is made too small. Therefore, one of the most satisfactory means of increasing economy and capacity is to increase the boiler capacity. Fuel is burned on many old engines at the rate of 180lbs. to 200lbs. per square foot of grate per hour, but this practice is very uneconomical, as the rate of combustion is so high that a great deal of unburned products of combustion are passed through the flues and smoke-stack without giving up all their available heat. On the other hand, if ample grate surface is provided, the rate of combustion can be kept down to reasonable limits and the economy of the engine increased materially. These economical conditions prevail when a deep firebox of ample size is provided, and the coal can then be burned under the best conditions.

Change of Type of Locomotives.—The majority of engines which have had the type changed in modernising have consisted of consolidations (2—8—0) to Mikado (2—8—2). Some consolidations (2—8—0) have been converted to eight-coupled switching engines by removing the truck and changing the distribution so as to throw the spring-supported weight farther back. As a general proposition, in considering the conversion of type, it is very necessary to make careful study of parts that can be used on the old locomotive, such as wheels, axles, rods, tender, &c., at the same time estimating or obtaining bids from builders as to what the work can be done for. Very careful consideration must also be given to ascertain whether, after the rebuilding has been accomplished, the railroad would be in possession of a really modern engine best adapted to perform the service for which it is intended.

Superheating Saturated-steam Engines.—In considering the advantages of superheated steam for locomotives, two general conditions may be noted. First, the economy in coal and water from the use of superheated steam. Secondly, the additional power made available by the more economical operation of the engine. If a simple locomotive, using highly superheated steam, consumes on an average 25 per cent. less fuel in the same service than the same engine using saturated steam, then 75lbs. of coal consumed with superheated steam will do the same work as 100lbs. used with saturated steam. There will be, therefore, an increase in indicated horse-power of

$$\frac{100-75}{75} \cdot 100 = 33$$

per cent. in favour of the superheater, and the actual gain in tractive power delivered at the drawbar will be even greater than this increase in indicated horse-power. The reason of this is that at the running speeds of trains about 40 per cent. of the indicated horse-power is absorbed by the internal friction of the engine and tender, leaving only about 60 per cent. to be transmitted to the drawbar. Consequently an increase of 33 per cent. indicated horse-power represents a much greater gain in dynamometer horse-power. Therefore, the friction of the locomotive being fairly constant, a much greater drawbar pull than 33 per cent. is available at the critical points. This large addition to the hauling capacity of a highly superheated steam locomotive may be applied either to the hauling of heavier trains or to higher speeds, or to both. An increase in total weight or wheel load due to the application of the superheater is relatively small, say 3,000lbs. to 4,000lbs., consequently increased tractive power is obtained without material addition to the weight.

Superheating affords the most available means of meeting in a very economical way the steadily increasing demand for more powerful locomotives without making them abnormally heavy. The application, to existing locomotives, of an efficient superheater capable of producing and maintaining a high degree of superheat, is equivalent to a considerable increase in boiler capacity, which is usually equivalent to a large increase in the hauling capacity of a locomotive. Not only is there considerable fuel economy, ranging from 20 to 25 per cent., in the use of superheated steam, but the general efficiency of the locomotive is so increased as to make it a necessary part of the equipment of all new engines and in many cases on old locomotives. By reducing the amount of fuel required for a given amount of work, the superheater increases the capacity of the boiler. Most locomotives, especially the older ones, are limited in their service by the amount of steam which the boiler will generate, so that a device which will do the same amount of work with, say, 25 per cent. less fuel, will obviously make a marked improvement, not only in economy and efficiency, but in the hauling power of the engine.

The limitation of locomotives in many instances is the inability to supply them with coal in sufficient quantities and at the proper time; therefore, any device which reduces the amount of coal necessary to be fed to the furnace is a long step toward improving the general efficiency of the engine. When new fireboxes or firebox tube sheets are required, it is desirable to consider the application of superheaters to such locomotives, the boilers of which are otherwise in good condition, whose age does not exceed, say, 15 years, or where new boilers are required on engines which otherwise can be used with advantage for some particular service. In such instances the application of superheaters to old engines is one which will well repay the outlay.

Brick Arches.—On the majority of engines a brick arch, properly installed and maintained in good condition, will produce a substantial saving in fuel, and also, by doing the work with smaller amount of coal, improve the general efficiency of the engine. Probably a saving of about 5 to 10 per cent. can often be made by the application of brick arches. It therefore follows that if without the arch it takes 100lbs. of coal to do a certain amount of work, that with a saving of 10 per cent. and the same amount of coal is fed to the firebox, an increase in the steaming capacity of 11 per cent. will be produced. The brick arch, by increasing the length of flameway in the firebox and preventing the gases and unburnt coal from entering directly into the boiler tubes before complete combustion has taken place, adds materially to the steaming capacity of the boiler and reduces the amount of coal necessary to be fired. Much benefit will also be derived from its use by preventing the formation of black smoke.

Outside Valve Gear.—Few locomotives at the present time are built with the inside or Stephenson valve gear. The size of locomotive has increased to such an extent that it is very difficult to maintain the eccentrics and the inside portions of the moving parts of a Stephenson gear in a satisfactory condition. The outside gears are much easier to lubricate, maintain, and inspect. Their moving parts consist mostly of articulations, provided with case-hardened pins and bushings in place of the large rubbing wearing surfaces, such as eccentrics and straps. The repairs and maintenance of outside valve gears to keep them in good condition are much easier and cheaper than the Stephenson. Furthermore, the reduced wear of the outside valve gear, by reason of its case-hardened pins and bushings, does not distort the gear to the extent that the wear of the eccentrics and straps does on the Stephenson gear. This is a very important matter, since the outside gear requires but little or no adjustment or resetting of valves from time to time, it being the custom on many railroads to make the gear what is termed "a blacksmith job," that is provided with no means of adjustment, so that any change required in valve setting must be made by upsetting or lengthening the rods in a blacksmith shop. Since there is no distortion due to wear with the outside gear, except that caused by the wearing of the main box in the pedestals, the position of the wedge, or wear of the shoe, it follows that the outside gear can be left alone without tinkering or adjustment to a greater extent than is possible with Stephenson or inside gears. Another advantage of the outside valve gear is that transverse bracing can be used between the frames to maintain them in proper vertical alignment and also for distributing the stresses.

Sizes of Valves—With superheated steam it is possible to use a smaller diameter of piston valve for the same size of cylinders than would be necessary for saturated steam. This is largely on account of the lightness of the superheated steam, which permits it to traverse the passages and ports at a much higher velocity. The sizes of piston valves used by a prominent locomotive builder in this country are as follows:—

Valve Diameter.	Cylinder Diameter. Saturated Steam.	Superheated Steam.
10in.	17 in. to 18in.	18 in. to 19in.
11in.	18½in. to 20in.	19½in. to 21in.
12in.	20½in. to 22in.	21½in. to 23in.
14in.	22½in. to 24in.	23½in. to 27in.
16in.	24½in. upward	27½in. upward

Extensive tests were made by the Pennsylvania Railroad on the locomotive testing plant at Altoona to determine the limitations in the use of piston valves varying from 7in. to 16in. diam., on locomotives having 22in., 24in., and 25in. cylinders. In all cases these tests were made with locomotives using superheated steam. The conclusions drawn from these tests led the Pennsylvania Railroad to adopt a 12in. diam. of valves for cylinders between 20in. and 27in. diam., and for cylinders 20in. and less, 8in. diam. valves. The results of these tests were published in P. R. R. Test Department Bulletin No. 23, 1914. Some of the conclusions drawn from these tests are as follows:—

"To establish a relation between the valve and cylinder so that the valve may be standardised, it may be stated generally that the diameter of the valve in inches for superheated steam should not be less than $0{\cdot}016D^2$ where D = the diameter of cylinder in inches. The 12in. valve is now used for cylinders between 20in. and 27in. diam., while for cylinders of 20in. or less, an 8in. valve is used. Cylinders above 27in. diam. have not been used for any class of locomotive of which there is more than one example, and a valve diameter for such cylinders need not be considered at present. Decreasing the valve diameter on a locomotive necessitates increasing the percentage of cut-off to obtain the same power at the same speed. This causes a longer valve travel."

From a maintenance point of view, it is of course desirable and economical for a railroad to carry in stock as few diameters of piston valves as possible. These considerations doubtless led the Pennsylvania Railroad to adopt the 8in. and 12in. valves as standard to be used in new construction and reconstruction wherever possible. These sizes adopted by the Pennsylvania Railroad are so much smaller than required by current locomotive practice in the United States, that some caution should be observed in adopting them without due consideration. For instance: The last statement in the conclusion, calling attention to the necessity of an increase in percentage of cut-off with the smaller valve diameter in order to obtain the same power at the same speed, is significant, since it necessarily follows that the expansive force of the steam is not utilised as advantageously, and it would therefore appear that some decrease in economy would result. The question of size of piston valves is of interest in the modernising of existing locomotives, since many railroads were committed to the use of slide valves because of their many recognised good qualities. With the general introduction of the superheater and its recognised necessity for modern engines, difficulty was experienced in applying superheaters to engines equipped with slide valves, because a film of oil could not be maintained by ordinary methods of lubrication between the valve and its seat and to the deformation of the valve and its seat at the higher temperatures.

A steam chest containing a piston valve that can be applied to existing slide-valve cylinders has been designed, manufactured, and tried on many leading railroads. At the present time it is estimated that upward of 75 engines having slide-valve cylinders are equipped with superheaters, steam chests, and piston valves. The sizes of piston valves which have been used for this purpose are 8in. diam., with ports up to and including 19in. in length; 9in. diam., with ports 20in. to 22in. in length, and 10in. diam., with ports exceeding 22in. in length.

The committee concluded its report with the following comment:—

Will the cutting up or scrapping of old locomotives continue at the same rate as in the past? This matter is related to the modernising of existing locomotives, since the length of time that an engine can be economically kept in good working order is dependent largely upon its weight and capacity. A locomotive can be kept in working condition indefinitely by renewing worn-out parts such as boilers, fire-boxes, frames, cylinders, wheels, axles, &c. Thus an engine can be maintained in good serviceable condition, so that it would not be called worn-out, if renewals are made when necessary. Such a method of continuous replacement is economically possible, provided the engine is suitable and powerful enough for the service.

Before the end of the last century there were no large locomotives such as we are accustomed to see to day. The tremendous increase in weight, size, and power came in the first 15 or 16 years of this century. In many instances this increase in size of locomotives was in advance of the bridges and roadway, so that it was necessary to rebuild a large portion of the main lines in this country. Now that this has been accomplished and the roadbeds laid with heavy rails and provided with bridges of sufficient capacity to carry the heaviest wheel loads, it is a question whether the increase in weight and power of locomotives can take place as rapidly in the next 10 or 15 years as in the opening years of this century. Assuming this is the case, and that there will be no such tremendous increase in the power of locomotives for the next few years, it logically follows, then, that their life may be increased by renewals of parts. Therefore, instead of taking 20 as an approximation of the number of years an engine would last in service, the life of the large modern locomotive may be increased for a longer period. During this time it would be necessary to renew many parts, and it is also probable that many economical devices which would fall under the head of modernising of existing locomotives could also be applied. It is therefore quite possible that a greater proportion of locomotives will be rebuilt or modernised in the future than in the past.

DIESEL ENGINE USERS' ASSOCIATION.

AT the July meeting of this association, after further new members had been elected, questions in connection with the use of tar oils as fuel in Diesel engines were further discussed.

Mr. Napier Prentice (Felixstowe) gave his experience in regard to the use of tar oil, which he had obtained from a local distiller. He had found difficulty in obtaining quotations, and in getting the work in hand of altering a Diesel engine so as to specially adapt it for the use of tar oil in the manner which had been successfully employed on the Continent, and he therefore decided to try the effect of using tar oil in one engine without any alteration. At about half-load he found this was not successful, as misfiring and a smoky exhaust occurred. He was advised to work with a sharp edge on the flame plate, and with this alteration and a slightly different quality of tar oil he obtained satisfactory results so long as the engine was not run below about three-quarters of full load. The blast pressure at all running loads was maintained at five atmospheres below the normal pressure used when running with petroleum fuel oil, and the cooling water outlet was restricted so as to maintain a temperature of 125° Fah. as against 110° Fah., which had been maintained when using the other class of fuel oil.

Mr. F. Banks Warner gave some information as to the general position in regard to the question of obtaining suitable supplies of tar oils, including delivery on site. At the present time the high railway rates for this class of business were a serious handicap to its development in certain parts of the country where local supplies were not available.

Mr. P. H. Smith read a paper on "Crankshaft Breakages in Diesel Engines." He attributed practically all cases of shaft fractures to a lack of alignment of the main bearings, due to wear, or to negligence during erection, or to defective foundations. He stated his views as to the best method of re-bedding a crankshaft and of securing perfect alignment, and as to the best proportions in the design of crankshafts for Diesel engines. Mr. Smith's paper is reproduced *in extenso* in another part of this issue. The association will resume its meetings next October.

Metallic Packing for Superheater Locomotives.—At the American Railway Master Mechanics Association Convention it was pointed out that some railroads had found the so-called 80-20 (80 per cent. lead and 20 per cent. antimony) mixture for metallic piston-rod packing incapable of withstanding the service imposed through the use of superheater steam, in consequence of which the 50-50 mixture (equal parts of lead and copper) has been substituted with good effect.

THE IMPORTANCE OF INCREASED PRODUCTION.

BY W. L. HICHENS.

In an address on the above subject delivered at the National Economy Exhibition, London, on June 29th, Mr. W. L. Hichens, chairman of Messrs. Cammell, Laird, & Co., Ltd., stated that as a large employer of labour all questions of labour and capital interested him more than anything else, save the war. The war had given them a new angle of vision in regard to many things. Before the war they lived in an age of individualism. The watchwords of the 19th century had been self realisation, survival of the fittest, *laisser faire*, and the interests of the individual. By an extension of meaning the same ideas were also applied to various groups of society. Employers organised themselves into federations, and working people organised themselves into trade unions, both of which existed for the purpose of seeking their own interests. Other classes of society followed suit, with the result that individual interests or class interests ranked first, and the interests of the country as a whole took second place. Politics was regarded as a game in which each section played for its own hand, and justice was supposed to reside in numbers. Then came the war, and straightway some 3,000,000 men were found ready to sacrifice their lives for their country. The clouds seemed to lift, the horizon extended, and they realised that patriotism ranked above individualism and class loyalty. It was seen clearly that the supreme interests of the country could only be secured by self-sacrifice.

It was seen at home—and even more clearly in the Dominions—that that newer and wider outlook also applied in regard to their view of the Empire. They realised that love of the Empire was no mere sham, but it was something that they grasped with an intense keenness, and for which they were prepared to lay down their lives if necessary. Many of them had begun to dream dreams, and to picture to themselves the use they would make of that wider form of patriotism after the war. They were surprised to find how far away they had drifted from the old individualism of pre-war days. That wider vision applied also in the case of national production. Before the war many men made it their ideal to put together a competence so that at the earliest possible moment they could retire and live happily ever afterwards. And how many young men and women there were who thought it no shame to live a life of idleness if they could afford to do so! But now the oldest "dug-out" in the country was anxious to "do his bit," ashamed to be found idle when there was work for all.

They realised now that there was an unlimited demand for everything they could produce, and he hoped that idea would not vanish when the war was over. It seemed to him that if it was essential for them to work as hard as possible to preserve their liberties, it would also be a valuable thing after the war to work as hard as they could for the sake of the happiness and welfare of the whole community. To-day there was an unlimited demand for everything they could produce. They wanted munitions for themselves, and for their Allies. They also wanted to produce as many other things as possible in addition to munitions, in order that they might be exchanged with other countries for commodities needed for war purposes. Munitions of war from abroad could be paid for in four different ways: (1) By the selling of American dollar securities; (2) by exporting gold; (3) by raising loans in countries with which they wished to trade. But the supply from these sources was limited. (4) Most important of all, they could exchange goods exported from this country for munitions, and that was the most satisfactory way of achieving their object.

A very great deal had already been done in the way of increasing their exports. The latest figures showed that the value of exports from Great Britain in May, 1916, was £47,000,000; in May, 1915, it was £33,500,000, while in August, 1914, it was only £24,000,000. That was, of course, a very large and satisfactory increase, and if they would only go on increasing at the same rate; if by this time next year the exports had again increased by one-third, and another £180,000,000 per year had been added to their value, everyone could see how enormously our position would be strengthened.

Surely much could still be done to improve output. Something also might be done by increasing Government organisation, but he did not think a very great deal could be done in that way, because he did not think the Government were very good organisers, and moreover, he did not think they had very good material to work upon. The sturdy independence of Englishmen, which was a very valuable quality and far superior to the unreasoning docility of the Germans, did not lend itself to Government organisation. Individual liberty had its price, but it was worth paying for. One of the things the Government could do was to devote more attention to organising the shipbuilding capacity of the country. Nearly a year ago he had tried to get a committee appointed of shipowners, shipbuilders, and Admiralty officials to deal with this subject. It was obvious that additional ships were badly wanted, and if such a committee saw to it that every shipbuilding yard was fully and continuously occupied on the type of work most suited to it, he was confident that the output would have been materially increased. He also thought it would have been a very great gain if the merchant shipping was more standardised in this country, so that they might for the time being concentrate more on quantity than on quality. But he was told that this was not practical politics. However, they would notice that quite recently a powerful body of practical shipowners had formed a company to produce just those standardised ships which the Government had declared to be outside practical politics. He was still in hopes that the Government would do something in this matter. But, speaking generally, they had to depend in the main on their own individual enterprise and effort. He felt confident that production could be largely increased, because it was still in them to make a very much bigger effort than they made before.

Before the war, statistics showed them that two-and-a-half times as much work per working man was turned out in the United States as in this country. Of course, in America they had far more labour-saving devices than were used here, and that fault lay mainly with British employers, who did not always take the trouble to find out the best and newest appliances because they felt they could rely upon a cheap labour supply. Responsibility also rested with the Government, because they had the most obsolete and antiquated income-tax regulations, which hampered them in writing off their capital within the life of machinery which they had purchased. In the United States it was commonly considered that machinery of certain types became obsolete in five years. In this country the rate of depreciation allowed for by the Treasury only enabled them to write off their plant in 20 years. The consequence was, every firm was tempted to go on using its old plant long after it had become antiquated. The question of depreciation under the income-tax laws was now a very serious one, far more serious with an income-tax of 5s. in the £ than it was in the days before the war, when it was only 1s. 2d. in the £. But although the statement that the output per man was 2½ times greater in the States may have needed qualification, everybody who had visited the States would bear out the fact that men worked very much harder there than they do here. He thought that anybody in close touch with labour would say, speaking generally, that there was still a considerable restriction of output.

The other day a well-known shipbuilder told him that in his shipbuilding yard 20 per cent. of his men were always out for the first quarter of the day, that was before breakfast; and 10 per cent. of the men were every day out for the whole day. That was far too high a percentage for war time. There was no need for men to keep such bad time as that. As another example, he mentioned that he was going over a shell shop the other day and noticed that the filling of trucks with 18-lb. shells was being carried out by women, whereas it formerly used to be done by men. He asked the manager what the effect of the change was, and was told that one woman did the work of five men! He would yield to no one in the great respect that he always had for the capabilities of women, but he maintained that it was not quite normal that women should be able to work five times as hard as men. The fact of the matter was that they had

been unable to shake clear altogether of pre-war ideas, and had not been able in all cases to acquire the new angle of vision. Restriction of output was the weapon used in the fight between labour and capital, and that weapon had not been thrown away by labour. For the moment there was a truce between the two parties, but it was a truce of the type which everyone would deprecate if it were applied as a solution of the present world struggle.

They needed a final settlement of the misunderstanding between labour and capital. It was easy to make out a strong case to show that labour should abandon this weapon at the present time. If they did, they would not really prejudice their position after the war, because the employer knew well enough what his machines were capable of and could distinguish between "cannot" and "will not." Restriction of output was a bad plan from the workman's point of view. It was only by increased output that the wages fund could be increased. Wages could only be paid out of production. If production was reduced, wages would have to be reduced. Labour argued that they ought to have a larger share of the profit paid to capital, but that would not go very far in improving the position of labour. The only way of paying considerably higher wages was to increase substantially the production of the country. Labour would probably not deny the truth of this, yet the argument would carry very little conviction to the working man. He would feel that the statement was one-sided. "Our difficulty," he would say, "is, that supposing we do increase production, we have no guarantee that the increase would go to us, for all experience goes to show that capital gets the lion's share."

Labour's grievance was that capital had taken more than its fair share of the good things of this world, that the distribution of wealth had been unfair in the past; and one must admit that there was a good deal of truth in their contention. If one studied the conditions of life in the poorer districts of the country, one had to admit that there was something wrong somewhere, and one could not help feeling that more of the wealth of this country ought to have gone in making the lives of the poorer sections of the community happier. He did not think it would be possible to make an appeal to labour to drop their weapon of restriction of output permanently unless a real effort was made to understand their point of view and to meet it fairly. The question of the distribution of wealth was a perennial source of difficulty, but that was no reason for leaving it severely alone.

Something had to be done soon if they wanted to avoid serious troubles after the war. He urged the Government to appoint at once a commission to enquire into the relations between labour and capital. Now was the time to act, because they had the wider vision which saw beyond individualism and beyond class loyalty to patriotism. It was only if they attacked the problem from that point of view that they could get anything approaching a satisfactory solution. The Government might reply that they had quite enough commissions to-day, but they had to remember that commissions were necessary to educate and crystallise public opinion in a democracy. Everybody ought to study the problem for himself, and realise that as a citizen in a democracy he will be called upon to decide what policy should be adopted. The present policy of drift would in the end lead to a revolution as surely as the policy of drift in regard to the army and foreign affairs led to a European war.

HEAT TREATMENT OF DROP FORGINGS.*

BY W. C. PETERSON

THE manufacture of drop forgings involves mechanical treatment consisting of forming the metal under a hammer, or in a forging machine, and heat treatment, which modifies the structure of the steel. The handling of the material, in the course of this treatment, has a great influence on the physical properties of the finished forging. All steels have a certain temperature or range of temperatures where the structure of the steel undergoes a change. This range of temperatures is called the critical range. Upon heating a piece of steel from atmospheric temperature up through the critical range and then allowing it to cool very slowly down to its original temperature, the steel appears as a very close crystalline structure. Upon further heating of the steel through its critical range, it is found, just upon emerging from this range, to have a very fine grained structure. Allowing it to cool from this temperature down through its critical temperature it is found that a very slight crystallisation takes place, after which practically no change in the structure is noticeable.

In drop forging it is necessary to have the temperature well above the critical range, since otherwise the metal would not be plastic enough to forge. As the forging is being heated beyond the critical range the grain size increases until, at the temperature at which forging begins, a very coarse crystalline structure is apparent. Application of heavy blows or of pressure soon breaks up this large grain, particularly if this hammering or pressing is continued sufficiently. To get the best results in drop forging the hammering should continue, for it must be remembered that large and crystalline grains will result if the steel be allowed to cool undisturbed, especially if the temperature is well above the critical range. This can easily be demonstrated by heating a piece of steel up to the proper forging temperature and hitting it just a few blows with the hammer and then allowing it to cool undisturbed. It shows a remarkable grain growth. On the other hand, if the steel upon heating to the proper temperature is hammered continuously to a point where the temperature is just above the critical range it will be found to have a very finely grained structure. It is well then to designate a finishing temperature on forged work, and the nearer this temperature is to the critical and yet above it, the better the forgings will be.

If the hot working of the metal is to continue to a temperature below the critical range the structure will still be fine grained, since crystallisation ceases at the beginning of this range, yet it would be distorted. Distortion in the structure of steel means decreased ductility, and in some cases even brittleness. Such a condition actually exists in the cold working of steel, since it is known that the structure existing below the critical range has no tendency to crystallise. The effect of cold working is essentially to distort, by stretching the elements of the structure in the direction of the force applied, causing decreased ductility and brittleness. Instances of the decrease in ductility are noted in the cold-working of steel where it is necessary to anneal before completing the final operation, such as in tube or wire drawing.

Although it may be possible to keep the finishing temperature as near the critical range as is practical it is found that the inner portions of a forging of small cross-section have a much coarser grain than those of the outside. It is extremely difficult to prevent this, for if the finishing temperature is correct for the outside the inner portions are hotter, causing grain growth, and again if it were possible to adopt the proper temperature for the inside portion of a forging, the outside would be affected by cold working, causing strains, &c.

In practice, then, conditions exist which are not ideal for forging, such as uniformity in finishing temperatures, and difference in structure from centre to outside. Heat treatment is destined to overcome to a marked degree the influences of these irregularities. It consists principally in heating the forgings to the proper temperature and holding this temperature constant until the entire forging is uniformly heated through, finally cooling to atmospheric temperature. In heating up the forging the temperature should be carried through the critical range, for in so doing any coarse structure which might have been present before is now destroyed, and the entire forging at this temperature presents an almost homogeneous structure. If the temperature remains below the critical range no change in structure takes place, and, of course, the purpose of heat treatment is defeated. But then there is danger also of heating too far above the critical range, since the steel when just out of the critical possesses the finest grain size and upon further heating these grains grow large and coarse.

The distance the temperature should be carried beyond the critical is largely dependent upon the size of the forging. A forging of small cross section should be quenched perhaps immediately upon the completion of the transformation, while a large forging, on the other hand, should be heated to a slightly higher temperature. This demand is made largely on account of the relative rapidity with which a small forging cools as compared to a large one.

* Paper read before the American Drop Forge Association, June, 1916.

In cooling from the heating temperature such mediums as air, oil, water, and brine are employed. Air cools much slower than water, and water slower than brine. It is very desirable to employ different rates of cooling because it is then possible to regulate the physical properties in the forgings. For example, if a forging is to be employed in such a way as to give ease in machining it would be cooled very slowly, and perhaps in the same furnace in which it was heated. This would be done, of course, at the sacrifice of strength. And, again, if it were desired that the forging possess strength and a certain amount of rigidity and hardness, it would be cooled more quickly perhaps in oil or even water.

The selection of cooling mediums in the heat treatment of forgings depends upon the constituents of the steel. With straight carbon steels the lower the carbon content the more rapidly the metal will cool. In this class of steels where the carbon is below 0·15 water may be used. This would increase the strength and yet not impair the elongation. If a steel of higher carbon content is quenched in water the elongation will be very low, necessitating a second or drawing heat. This reheating is absolutely necessary when two forgings of different size and of medium carbon content are to be quenched, if the same physical properties are to be retained.

With forgings made of high carbon alloy steel there is danger of cracking in water. On some forgings where the adjoining cross-sections abruptly vary in size, even when oil is used as a quench, the second or drawing heat must be carried out almost immediately after the quenching heat. This is due to the great difference in the rate of cooling of the various cross-sections, resulting in strains which eventually produce cracks. In forgings of this character it has been found very beneficial to first anneal the material so as to facilitate the machining operations which remove as much metal as is possible, leaving only enough for light cuts. Where possible, only sufficient stock for grinding should be left. This would no doubt leave the forging in many cases with more uniform cross-sections, making a more uniform heat-treatment possible. This method has been instrumental in increasing the strength of important automobile forgings at least 30 per cent. The advantage has not ended here, for the cost of tools and their upkeep has been considerably reduced on account of the ductility of the forging in its rough state when treated in this manner.

NEW PATENTS.

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1915.

Rotary compressors, pumps, and engines. Marks. 9499.
Turbine installations for ship propulsion. Parsons, Walker Cook, and Douglas. 9570.
Semi rotary engines. White. 9622.
Temperature controlling devices. Hall. 9650.
Internal combustion engines. Thrutchley. 9819.
Internal combustion engines. Kelly. 9910.
Two stroke cycle internal combustion engines. Lozinski. 9920.
Tool holders. Amborn. 10102.
Valve casings for internal combustion engines. Daimler Motoren Ges. 10416.
Expanded metal manufacture. Clark. 10484.
Apparatus for controlling the carburetters of internal combustion engines. Arthur Deacon & Son, Ltd., and Berry. 11362.
Silencing the exhaust and utilising the waste heat of internal combustion engines. Rixon. 11641.
Apparatus for determining the hardness of a body. Vickers, Ltd., and Smith. 11936.
Tools for cutting metal bars. Ashton. 11984.
Carburetters for internal combustion engines. Merriam & York. 12134.
Sand moulding machines. Blakeborough & Boyd. 12491.
Carburetters for internal combustion engines. Brown, and Brown and Barlow, Ltd. 12541.
Carburetters for internal combustion engines. Ransom. 12795.
Feed gear for circular sawing machines for cutting metal. Bennie. 13361.
Automatic hammers. Boden. 13451.
Ignition devices for internal combustion engines. Nielsen. 13964.
Machinery employed in coating metal sheets or plates with tin, terne, or other metal or alloy. Jenkins. 14537.
Pulleys. Bullivant & Schermuly. 15598.
Form of universal joint. Pentony. 16436.
Means for indicating the level of liquids. Doxford. 16751.
Vaporisers of internal combustion engines. Gardner. 16983.
Turbine pumps. Rufener & Wiesengrund. 17283.

1916.

Motor power plant. Westinghouse Machine Company. 199.
Parting machines for cutting off lengths from bars, billets, and tubes. Clifton & Baird, Ltd., and Clifton, C. H. 1788.
Valves and valve-gear of internal combustion engines. Wilkinson, H. O. 2734.
Lathe chucks. Justice, P.M. 3031.
Transmission gearing, especially for automobiles. Harriman, G. V. 6913.

ELECTRICAL, 1914.

Electric incandescent lamps. Julius Pintsch Akt.-Ges. 17022 and 17023.

1915.

Wireless telegraph and telephone systems. De Forest. 6486.
Electron discharge apparatus, and method of operating the same. British Thomson Houston Company. 9690.
Electric heating elements. Dowsing & Huntley. 9828.
Electrical transformers. Harlow. 9921.
Electric joint. Scholes. 9964.
Transmitters for wireless telephony. Marconi's Wireless Telegraph Company, and Trost. 11831.
Miners' electric lamps. Bellamy. 13807.
Electric incandescent lamps. Hunter. 13943.
Electric stoves. Crary. 14783.
Electric lamp holders. General Accessories Company. 15459.

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Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
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Antimony	£95/–/– per ton.
Brass, rolled	1/3⅝ per lb.
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,, ,, (solid drawn)	1/2¾ ,,
,, ,, wire	1/2⅞ ,,
Copper, Standard	£97/–/– per ton.
Iron, Cleveland	82/6 ,,
,, Scotch	— ,,
Lead, English	£29/–/– ,,
,, Foreign (soft)	£27/15/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	29$\frac{15}{16}$d. per oz.
Spelter (American)	£50/–/– per ton.
Tin, block	£166/–/– per ton.
Tin plates, I.C.	28/– per box.
Zinc sheets	£72 per ton.

A Sensitive Magnetometer.—A paper, entitled "A Sensitive Magnetometer," by Dr. P. E. Shaw and Mr. C. Hayes, was read at a recent meeting of the Physical Society of London, by the former. A torsion balance of extreme delicacy carries a pair of purest silver balls, each 3 gm. weight. A solenoid with horizontal axis passing through one of the silver balls, is brought close to the balance. On exciting the solenoid, divergent fields of known strength are obtained in the region of the ball. The resulting attraction of the ball to the solenoid is shown by a mirror reflecting a distant scale to a telescope. The couple on the torsion beam required to produce 1 mm. scale deflection is 4·5 by 10^{-7} dyne cm., and this torsion balance is 10^6 times as sensitive as any known to have been used previously in this kind of work. The results of these experiments are: (1) The magnetic properties of the silver are ascertained even for weak fields of 1—10 gauss. (2) The silver has a pronounced retentivity; this effect being presumably due to the small trace of iron impurity. (3) The relation of susceptibility of the silver to the field used is found. The susceptibility of each of the constituent materials (*a*) pure silver, (*b*) residual pure iron, appears to be greatly modified by the presence of the other material.

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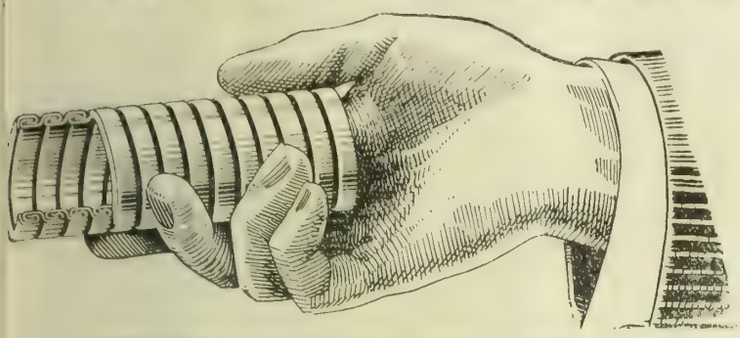

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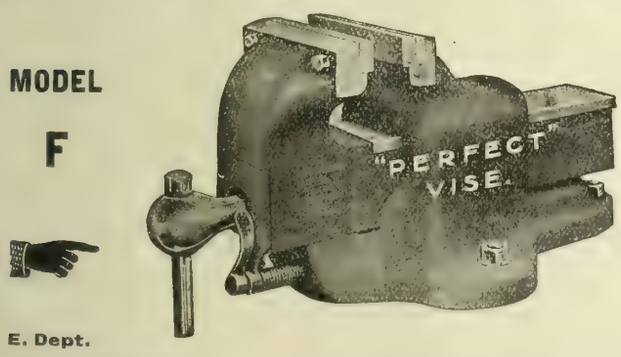

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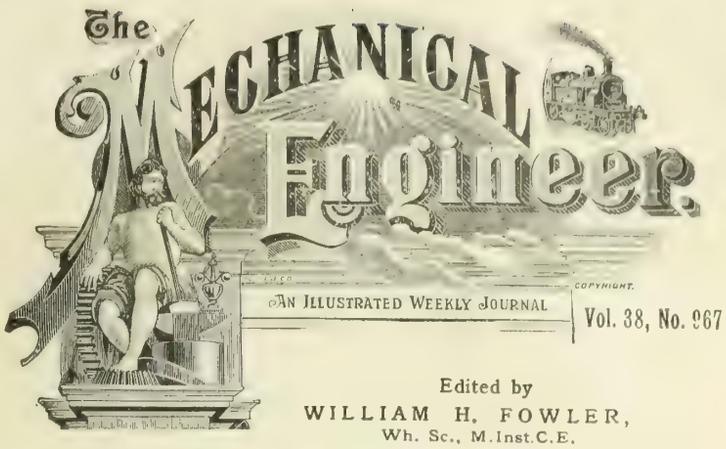

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Science and Industry.

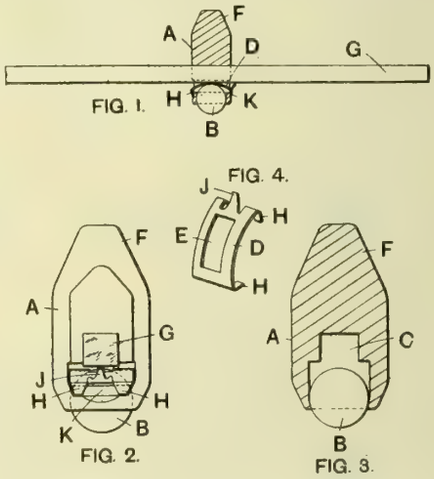
The value of intimate co-operation between the laboratory and the workshop has long been urged by those who have studied the conditions which make for efficiency in engineering industries and realise the importance of science as a weapon in international competition. It is easier, however, to point out defects than to get them remedied. Our conservatism is proverbial, and a strong stimulus always seems necessary to rouse British energies to full activity. The war has done this in many ways, and none of its after-effects on engineering industry will be more conspicuous or beneficial than the exaltation of scientific education and research work. A satisfactory feature of this is that steps are being taken to meet our needs now and not deferred till war is concluded and a multitude of other social and political questions will clamour for attention. The Consultative Committee of the Board of Education has already issued an interim report containing a number of valuable suggestions with respect to the generous issue of scholarships to students from evening classes and work schools to technical colleges and universities, to encourage them to develop their personal capacities so that they may serve the needs of the nation in the manner for which they are best fitted, industry, agriculture, and commerce being regarded as the principal need, and higher education as a means to this end. The activities of the various technical societies are also being enlisted in various ways, and we are pleased to note in this connection the action that has been taken by the North-east Coast Institution of Engineers and Shipbuilders. Research work, we know, is of special importance in engineering, and its character varies widely and the term does not apply exclusively to that which is conducted by the professional staff of a technical college. In progressive works investigations of this kind are always being conducted more

or less. Development in fact is almost impossible without it. There are, however, many questions in engineering on which competent and impartial outside investigation, when it can be secured, is of great advantage, and the North-east Coast Institution has recently made a good start with its Research Committee by acceding to the request of a well-known firm in the north to investigate and carry out exhaustive tests of apparatus having for its object the more economical production of power by marine steam engines. By its action it will be the first of the influential technical institutions actively to promote the progress of the industries with which its members are associated by officially making and recording tests of new apparatus developed by them. In the introduction and development of improved apparatus much depends on an authoritative pronouncement concerning the results claimed, and this can best be secured through the verdict of independent bodies who are not influenced by commercial considerations. Such findings would be at the disposal of all, a spirit of industrial co-operation would be engendered that would not only be to the advantage of the industry immediately concerned, but for the good of the nation as a whole. The data accumulated would represent the collective knowledge of each industry, and its publication would prevent much overlapping of experimental work that probably now prevails and often involves unnecessary and heavy expenditure. Again, experiments which do not appear to promise any definite result are often broken off before an ultimate conclusion is reached, and probably in some cases new discoveries are missed by us and rediscovered later by our competitors abroad. The necessity for the establishment of some measure of ordered and systematic research has recently been recognised by the manufacturers in certain trades. Previous to the war both the Institution of Mechanical Engineers and the Institution of Electrical Engineers gave official recognition to the value of research organisation by appointing research committees. It was not, however, until war had broken out and we had unpleasant proofs of the dependence upon foreign research of many of our industries—the chemical industry, for example—that definite action was taken to meet the demand for closer co-operation between science and manufacture. A notable sequel was the appointment by the Government, in July, 1915, of a Scientific and Industrial Research Committee. Little is as yet known of the actual work carried out during the year by this committee. It may be that the work will prove of national value, but the existence of such a committee by no means closes the door to research work such as that which has been so promisingly begun by the North-east Coast Institution of Engineers and Shipbuilders.

APPARATUS FOR DETERMINING HARDNESS OF METALS.

THE accompanying illustrations show a simple design of apparatus for determining the hardness of metals, the invention of Messrs. Vickers, Ltd., Vickers House, Broadway, Westminster, London, and Mr. Robert L. Smith. Fig. 1 is a sectional elevation of the holder with a standard bar adjustably retained therein. Fig. 2 is an end view on an enlarged scale of the holder with the standard bar and resilient member in place, and Fig. 3 is a section with the bar and resilient member removed. Fig. 4 is a perspective view on an enlarged scale of the resilient member. B is the steel ball supported in the lower part of the holder A. C is the opening in the holder for the reception of a standard bar G. D is the resilient member having the aperture E and tongues H and J. The tongues H engage ledges or recesses K on the holder and retain the member in position and the tongue J which is upturned serves as a pointer. F is the part of the holder which acts as an anvil.

To obtain the approximate hardness of an article under examination, the ball holder A is slid on to one of the bars G possessing the same degree of hardness as that which the article under examination should possess. The bar G is then held by its end so that the ball rests on the article with the axis of the holder perpendicular thereto, and the anvil F of the ball holder is given a slight blow with a hammer; the holder is then slid along the bar so as to expose the impression or indentation made on the standard bar, and this impression is compared with that which was simultaneously made on the article by the same blow of the hammer. If the two impressions are the same in size, the hardness of the article under examination is the same as that of the standard bar. If, however, there is any appreciable difference in the size of the two impressions, the operation is repeated with a harder or softer standard bar until equal impressions are obtained with the same blow, the figures at the end of the standard bar then giving the degree of hardness possessed by the article under examination. The method of using the pointer J is to slide the holder A up to near the end of the bar, so that the pointer is at or adjacent the extreme end thereof. The holder is then in position for taking the first test. After each successive test the holder is moved down the bar until the pointer registers with the inner edge of the impression that was last taken. In this way the pointer always indicates the last impression and any danger of the impressions overlapping is prevented.



APPARATUS FOR DETERMINING HARDNESS OF METALS.

If desired the ball holder may be made sufficiently heavy to act as a hammer, or an additional weight may be placed upon the anvil so that the holder may itself serve to give the blow without the aid of a hammer. The ball is retained in the holder by slightly "bruising" or "centre popping" the annular surface with which it is in contact.

The chief utility of the tool, however, will not be so much in ascertaining the particular degree of hardness of an article as in obtaining very promptly and reliably information as to whether the article under examination comes within certain required limits of hardness, this information being what the manufacturer really requires. For example, supposing a certain batch of hardened and tempered steel articles should be specified to have a resulting hardness not below 400° and not above 500°. To ascertain whether the articles come within this degree of hardness it is necessary to make the aforesaid hammer test with a standard bar of 400°. The articles that show by the impressions resulting from the test that they are softer than this standard may be returned for rehardening or altogether rejected, and the articles which have impressions showing that they are only slightly softer than the standard may be passed as satisfactory. To ascertain if the articles passed as satisfactory come within the higher limit of 500° they are subjected to the hammer test with a 500° standard bar and are passed or rejected as inspection of the impressions may decide.

SUPERHEATER LOCOMOTIVES.*

On January 1st, 1916, there were 15,666 superheater locomotives in service in the United States and Canada, practically all of the fire-tube type, as follows:—

Superheaters applied at time of construction of locomotive	9,900
Superheaters applied to locomotives already in service	5,766
	15,666

With the exception of one prominent railroad, very few locomotives, originally equipped with slide valves, have been changed to piston valve and had superheaters applied. With the exception of 142 Mallet locomotives, equipped with superheaters, having slide valves on the low-pressure cylinders, very few superheater locomotives are equipped with slide valves. The railroad on which these Mallet locomotives are operating is experimenting with a view of applying piston valves. Therefore, the committee does not feel this subject can be thoroughly discussed at this time.

Of the railroads reporting, 99 per cent. of the superheater locomotives were equipped with brick arches. The use of brick arches is specially recommended on superheater locomotives, where practicable, as it causes more perfect combustion, better distribution of heat in the firebox, protects the flues and sheets and effects a reduction in smoke and sparks and cinders in flues and front end. In extreme bad water districts the application of arches should be determined by local conditions.

There is a decided difference of opinion as to the advisability of equipping switching locomotives with superheaters, as follows: Some railroads maintain the same relative economies are effected through superheating switching locomotives as are obtained by superheating road locomotives. Other railroads will not give consideration to superheating switching locomotives until all available road locomotives have been equipped, owing to the greater returns to be obtained. The committee commends the application of superheaters to switching locomotives, but considers their application to road locomotives as being generally of greater importance.

It is felt no set rule can be formulated covering the application of superheaters to existing locomotives, as age, general condition, capacity, and further service to be secured must govern. Several railroads reported having superheated locomotives 10 to 15 years old.

The return tube, top header, double loop superheater is the type most generally used. In view of the many complete reports which have already been rendered on tests covering the economies effected through the application of superheater, and superheater and brick arch, the committee did not believe it necessary to publish further data in this report. However, on a conservative basis, it is felt that an economy of 15 to 25 per cent. in fuel and 20 to 30 per cent. in water consumption can be expected in every-day operation through use of the superheater and brick arch. Numerous tests have shown greater economies. On a number of railroads the application of superheaters has reduced the time of freight trains on the road 10 to 15 per cent. and eliminated one stop for coal and two stops for water over one freight engine division.

It is generally felt by all, and proved by some careful comparative tests, that the cost of repairs (maintenance of equipment) is greater for locomotives equipped with the superheater and brick arch. However, for the railroad as a whole, the reductions effected in the cost of coal and water and the increased general efficiency (conducting transportation), offset this many times over.

As a general proposition, no changes are necessary in the front end arrangement, due to the application of superheater, aside from those made on account of superheater elements, header, and damper. Replies received indicate no great variation in the size of exhaust nozzle tip between saturated and superheated locomotives of the same general characteristics.

The committee stated that the best results will be obtained in operating superheater locomotives by carrying about two gauges of water, with full throttle on short cut-offs, so far as operating conditions will permit. The engineer should also be required to crack the throttle when drifting.

The committee's investigation developed that the majority of superheater locomotives are equipped with hydrostatic lubricators without booster, although a considerable number of railroads are using the hydrostatic lubricator with the booster attachment. The booster is of value if the hydrostatic lubricator has a restricted equalising passage. If the hydrostatic lubricator is designed with the proper size equalising passage, the booster attachment is unnecessary, as its principal function is to compensate for the restricting equalising passage. The use of the force-feed lubricator is very limited, but a number of railroads are experimenting with this type at the present time. The use of an independent feed for lubricating the cylinders is limited. It is the opinion of your committee that this is unnecessary and should be discontinued, as it is very questionable if any benefits are being derived therefrom.

The majority of railroads are now using a superheat oil for the lubrication of superheater locomotives, stating that it does not carbonise and better results are obtained. It generally has been necessary to increase the valve oil allowance 20 to 25 per cent. for the superheater locomotives over the allowance for saturated locomotives of similar type and size. However, this does not apply in the same proportions to bad water districts, where superheating has reduced the foaming and eliminated water being carried over into the cylinder, in which cases no increase in oil allowance has been necessary. Various methods have been tried for the use of graphite on superheater locomotives, but the replies received indicate the majority are not using graphite for lubricating superheater locomotives.

Trouble has been experienced with carbonisation of oil in valve spools and piston heads, and to a lesser degree in the air pumps. In the valve spools and piston heads this has been remedied by decreasing the amount of oxygen drawn into the cylinder by drifting with a partially open throttle or drifting valve. The use of superheat oil will also decrease the trouble. The application of superheaters to locomotives equipped with slide valves has been so limited, the committee does not feel warranted in discussing the system of lubrication for that type of locomotive at this time.

Vacuum relief valves are generally used, although there is some question as to what benefit, if any, results. The majority of replies to the committee's enquiry received indicated that the by-pass valve is not in general use on superheater locomotives. These have only been advocated for large-cylindered locomotives, to take care of the high compression in the cylinders.

A number of railroads are now using, and others are experimenting with, drifting valves, either manually or automatically operated. When drifting is done with the throttle valve, on superheated locomotives, superheated steam is used. When drifting valve is used, either manually or automatically operated, saturated steam is used. Generally, no distinction is made as to size of drifting valve or steam connections between large and small locomotives in passenger and freight service, and for the sake of standardisation such practice is desirable. When locomotives are not equipped with by-pass, automatic or manually operated drifting valve, or other drifting valve in the cab, the throttle should be cracked while drifting a sufficient amount to prevent the admission of air. This will decrease carbonisation.

Very little experimenting has been done in the application of pyrometers to locomotives, outside of special tests, but the committee believes it is desirable to make tests from time to time to ascertain the degree of efficiency being obtained. In view of the initial cost, it is felt that portable instruments would answer the requirements, a certain number for each division, to be transferred from one locomotive to another. The pyrometers should be adjusted at regular intervals, in order to obtain accurate readings.

Some difficulty has been experienced due to superheater headers cracking, units leaking, and packing melting. As a general proposition, however, the trouble has not been serious from these sources. There are no comparable data available as regards engine failures as between superheated and saturated locomotives. Better design or foundry practice is recommended as a remedy for the trouble with the headers and better workmanship for the units. The standard set of tools as recommended by the superheater manufacturers is

* Report of a committee presented at the June, 1916, convention of the American Railway Master Mechanics' Association.

recommended for adoption as standard for the care and maintenance of superheaters.

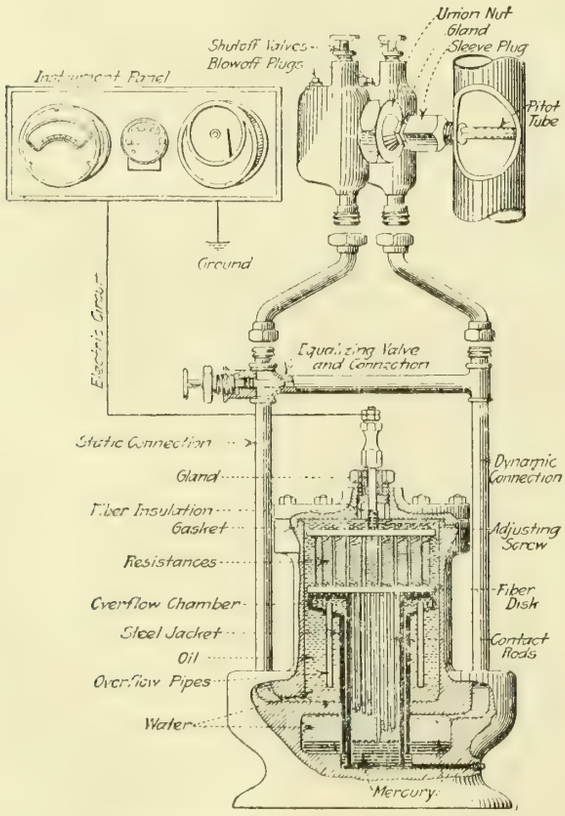
A number of railroads are welding all flues in the back flue sheet successfully, the welding being done with the ordinary types of welding equipment.

With the exception of one prominent railroad, all railroads reporting are using superheater dampers in the front end satisfactorily.

The investigation develops that a number of railroads have had more cracked cylinders and saddles with superheater locomotives. They have now adopted outside steam pipes, which involved change in design of cylinders, on superheater locomotives.

ELECTRICALLY-OPERATED FLOW METER.

A NEW design of flow meter for water, air, steam, and gas has recently been introduced by the Republic Flow Meters Company, 565, Washington Boulevard, Chicago. The meter is shown in the accompanying cut, for which we are indebted to "Engineering News." It comprises a pitot tube and a differential pressure gauge, both of special construction. The pitot tube comprises two tubes going entirely across the flow pipe, the static- and dynamic-pressure openings being two lines of small holes at the midpoints of equal annular areas, by which it is reported a true average velocity pressure is obtained directly. The lines of holes are 180° apart. The differential pressure gauge is a casting with two reservoirs, one above the other and connected by a vertical shaft. This arrangement takes the place of the usual U-tube. In the lower reservoir is mercury. Above this is water, and on top



ELECTRICALLY-OPERATED FLOW METER.

of all is oil. As shown in the sketch, in the reservoir well is a steel tube supporting a series of resistance spools and dependent contact rods. There is a constant-voltage (40 volts) alternating-current circuit flowing from a special transformer through the resistance and mercury to the pipe connections, and thence to indicating and recording instruments. As velocity and impact pressure rises, mercury is forced from the lower reservoir up the contact-rod well, short-circuiting more and more of the resistance, and displacing oil (which in the tube well rests on the mercury). The resistance units are so proportioned that the current is kept proportioned to the square root of height of mercury column, and so to the pipe velocity.

PAINTING BY DIPPING, SPRAYING, AND OTHER MECHANICAL MEANS.*

BY ARTHUR SEYMOUR JENNINGS, F.I.B.D.

IT may safely be taken as a fact beyond doubt that the application of paint, japan, enamel, and varnish by mechanical means, in contradistinction to the old-fashioned method of using brushes, effects an enormous saving of time, and to some extent of material also. It should also be recognised that the result from the point of view of both durability and appearance is a distinct improvement on the older method. In the United States of America dipping, paint-spraying, and the application of paints and varnishes by other mechanical means are employed almost universally in the industries, and in this country such methods have been successfully used in certain factories for many years past. Of late there has been a remarkable increase in this direction in the United Kingdom, although there are not a few manufacturers who still seem slow to adopt modern methods.

It is remarkable to note that a great number of firms who have given some consideration to the subject are inclined to the idea that while paint or its equivalent may be successfully applied by mechanical means in other industries than their own, it is not suitable for the particular one in which they are engaged. Closer examination, however, proves that there are very few trades indeed using paint in which the processes may not be successfully employed, and it may surprise some of those present to learn that in at least 250 different industries dipping or spraying may be successfully and economically employed. A few of these may be mentioned in order to indicate the diversity of the articles dealt with. Paint is applied by dipping to agricultural implements on a very large scale, to casements, bedsteads, piano cases, barrows, reaping machines, cans, and a great many other articles. By spraying, paint, varnish, japan, and various other protective liquids are applied to shells and to confectionery, to celluloid buttons and to motor-cars, to bird-cages and to dynamos, but the list could be extended almost indefinitely.

In my investigation of the subject I have come across a few firms who have tried one or other of the methods mentioned, but have abandoned them on the ground that the result has not been satisfactory—never, be it remarked, because they were found to be too expensive. Investigation has proved that such cases of failure have arisen either because a suitable apparatus was not chosen for the particular work in hand or the right sort of paint or japan was not used. The last cause of failure is the most frequent, as, for instance, a case placed before me some time since, in which small iron castings were painted by dipping but were found to stick together and not dry properly. Here the japan used was not suitable for the purpose, and it will be readily seen that paint or japan which might answer well if applied by means of a brush would not be suitable for application by dipping.

Without going at this stage into the question of other failures, it may be remarked that an idea prevails that the cost of plant necessary for carrying out these processes is prohibitive. This is altogether a mistake. A spraying machine with the necessary plant could be purchased for £30 or £50, although a large plant would, of course, cost very much more. The same is true in the case of dipping. If the articles to be painted are very large and very elaborate, the plant will obviously be somewhat expensive. For many purposes the tanks, hoists, &c., may be of a very simple character, as, for example, iron and steel sashes which are dipped into a narrow tank containing paint would require only a simple form of hoist with hanging rails and metal dripping floor adjoining the tank; or, simpler still, a mere box-like tank, in which tapered varnish and paint cans are dipped by hand, a piece of wood being inserted in the neck by which to lift them in and out. The cost of such a plant need only amount to a few shillings.

It will be convenient now to divide the subject up under various heads, viz., (*a*) painting by immersion; (*b*) by spraying by means of compressed air; and (*c*) other mechanical means.

* Paper read before the Royal Society of Arts, April 5th, 1916.

Taking these in order, a dipping plant usually consists of a tank (preferably metal lined) which contains the paint or varnish into which the article to be painted is plunged bodily. Clearly it must be of sufficient size to hold easily the article to be dipped. In the case of agricultural machinery, farm and military wagons, &c., the size and depth have to be considerable, and in this case, as a rule, an agitating apparatus at the bottom is desirable. One form consists of a shaft passing from end to end at the bottom of the tank, and provided with a paddle, while over it is provided a metal frame which may be roughly described as a horizontal venetian blind, the slats of which may be turned vertical when the agitating apparatus is working. This fitting is provided with the object of preventing the paddles being clogged by the settling paint, but it also serves to catch any pieces of wood, nails, &c., which may accidentally find their way in. As a matter of fact, a good dipping plant does not settle out to any extent, and it is sufficient if the agitating apparatus is operated each day for 20 minutes or so before starting work, and for a somewhat longer period on Monday morning.

Another form of agitating apparatus is provided with a worm for agitation instead of a series of paddles.

As already indicated, for dipping such articles as iron sashes a very narrow but deep tank suffices, and, in this case, as in many others, the agitating mechanism may be wholly dispensed with, because it must be remembered that the mere fact of plunging an article into the paint and immediately withdrawing it has the effect in itself of stirring up the paint.

Iron bedsteads are coated nowadays almost invariably with paint or japan by plunging the parts into japan, and these are afterwards stoved or baked. Iron frames of mangles and many other similar parts are also painted by dipping. Perhaps no better illustration could be given of the high degree of finish obtainable by dipping than the fact that piano cases may be finished by the method, the parts being lowered bodily into the varnish tank. Time will not permit me to give the details of the process, but I may state quite definitely that the finish is quite as good as that obtained by the use of brushes, and that the extra amount of varnish required is only about 5 per cent. I would very emphatically state that if the very fine finish which is necessary for pianos can be obtainable by dipping there can be no paint, varnish, or japan finish too difficult to obtain by the method. In effect, it simply means a careful study of the requirements for the particular work in hand.

Adjoining the tank must always be an inclined metal-lined floor, over which the articles can be held to drip for a few minutes, and this floor should be connected with a trough leading to an underground tank to hold the superfluous paint, which should pass through a grating and may be pumped into the main dipping tank as required, or, if desired, the arrangement may be such that the superfluous paint drains directly into the dipping tank.

Just as the size of the tank will vary with the dimensions of the object to be dipped, so will the type of hoist employed differ according to circumstances. I have seen a rope over a pulley used for very simple work, such as bedsteads, but as a rule a pneumatic or electric hoist is the cheapest in the end, particularly if it is worked in connection with a trolley, because it must be remembered that it will be necessary to provide a more or less elaborate system of overhead rails on which the articles can be hung to dry after dipping.

As a rule, the paints employed are sufficiently hard to receive a second coat within, say, four hours; and the system adopted at Woolwich Arsenal is a very good one, which may be confidently recommended. Two tanks are provided, one at each end of a very long room with rails between. The wagons are dipped at one end, proceed very slowly towards the other end of the room, where they are sufficiently dry to receive a second coat, and on turning receive a third coat at the first tank.

I should like to emphasize the importance of a careful consideration being given to the question of the overhead rails, as I find from my inspection of a large number of factories that many of them are quite deficient in this respect. As in all details of engineering works, a saving of labour is essential to economy, and it is well to have the rail so arranged that the work passes from the finishing room to the tank or tanks, and thence to the storage or shipping department. If this is done on a well thought out basis great speed can be effected.

It will be understood that the article being painted remains in the paint only a few seconds, that it is then stationed over the dripping floor for perhaps five minutes, and then proceeds along the rails for further treatment until it is finished. The question will at once occur whether this method does not produce drips, or what painters call "fat edges." The answer is, that if this occurs the paint is not properly made for the purpose. As a matter of precaution, one painter usually stands by each article as it is suspended over the dripping floor, and with a brush removes any small drips or fat edges which may occur. This labour, however, is very slight. Sometimes it is desired to put on a different-coloured finish to the work than that which is put on the undercoats; it is clear that this may be effected by using a different tank.

Before proceeding to describe paint-spraying or painting by means of compressed air, it may be convenient to compare the method with that of dipping. Without dwelling at any length on the subject, which is of a somewhat controversial character, it can be stated briefly that in arriving at a decision as to the respective merits of the two processes one can only be guided by the shape and size of the particular article which is to be painted. A reaping machine, for instance, is of so intricate a character that plunging it bodily into the tank is certainly preferable to spraying; on the other hand, there are many articles where spraying produces far better results than the dipping process. Sometimes both methods are used in conjunction; for example, the first or priming coat can be given by dipping and the final coat of varnish sprayed on. Again, spraying can be used in cases where the whole article is not required to be painted, as, for instance, the body of an automobile, which if plunged would receive paint on the inside as well as the outside, which is not desired. A better way would be to spray over the whole of the outside surface, although this method, as I shall explain later, has to some extent been superseded.

There are about a dozen different makes of paint sprayers on the market. It is hardly within my province to recommend any one of these as being superior to the rest, but those interested should carefully compare the construction and first cost before arriving at a decision as to adopting either. With one or two exceptions these machines all work in the same manner. Paint, varnish, or other liquid is contained in either a cup attached to the spraying apparatus when the quantity required is small, or in a small tank connected up with tubing. Take, for example, the "Aerograph," which was the first of its kind placed on the European market. A cup containing the paint is screwed on when only a little paint is required, but when the supply is to be continuous a cap fits in the same position, and the paint comes through a supply tube. The air is supplied through a flexible tube, and there is a finger lever which controls both the air valve and the colour valve in the nozzle, so that little or much paint may be allowed to pass into the current of escaping air. This may be considered to be a general principle upon which all these sprayers work, with one or two exceptions. The amount of air pressure varies very largely with the consistency of the paint, but, generally speaking, thin liquids and varnishes may be sprayed with 18lbs. to 20lbs. to the square inch, while a maximum of 50lbs. will cover nearly all classes of paint and similar products. In cases of very thick liquids heat may be applied to the paint tank, which will facilitate the operation to some extent.

The next sprayer is known as the "Midland." Its claims to superiority are chiefly simplicity of construction, solidity of working parts, and ease of cleaning.

Another form of sprayer is the "Invincible." This instrument is so arranged that it may be used with the air pressure only if required to dust the article about to be painted.

The "Airostyle" is the next type of sprayer shown. It is made in various patterns and sizes for use with different kinds of work, and is one of the most popular instruments of the kind on the market.

The "Aeron" is another type, and the spraying is done

through the cup holding the paint, excepting in the case of a considerable amount of work being done, when the paint will be placed in a container holding several gallons and held in an elevated position.

The "Eureka" is constructed on an American model. It is used with the cup only and is conspicuous for the absence of complicated parts. It is very suitable for work in which it is desired to change the colour frequently, as any number of cups filled with different colour may be on hand, and the transfer from one to the other takes but a minute or so.*

Having briefly described the principal spraying apparatus available the next provision necessary is (*a*) the supply of compressed air, (*b*) the exhaust, and (*c*) the cabinet in which the spraying is done and which should be fitted with a turntable. There are various forms of air compressors, ranging from a small and simple one for a single spraying apparatus up to those larger and more elaborate which are required where a number of sprayers are in use. The compressors must be designed to give an absolutely pure supply of air, free from oil and grit, and the air main must be so arranged as to avoid any trouble due to condensation. For high-class work a suitable air filter should be fitted to the intake of the compressor. It should be of large diameter, and have a gauze screen and wad of cotton wool.

As already intimated, the spraying should be done in a cabinet fitted with an air exhaust. Unless this is provided the operator may be seriously injured by inhaling the fumes from the paint or varnish or the paint itself. The exhaust is usually produced by fans, and in large works the exhaust main connects up with all the different cabinets. This question of masks is one which solves a good many of the problems surrounding the subject of paint spraying. By using masks or stencils, or both, almost any work can be done. For instance, I was recently consulted by a toy manufacturer in a large way of business as to the most economical method of painting red lines on iron parts of toy standards. I recommended a spraying machine to be used with stencils of thin metal through which the lines should be cut with breaks at intervals to hold the stencil together. Going back for a minute, it may be mentioned that in dipping articles into paint any portion which is not required to be painted may be protected by the application of a little vaseline, and this can be rubbed off when the rest of the work is dry.

Before leaving the subject of spraying, a few words may be said as to another type of apparatus used in the open for 16 operators on small work. These cabinets are fitted with glass sides, and it may be here mentioned that ample light, either natural or artificial, must always be provided, as otherwise some part of the work to be sprayed is nearly certain to be missed. The light should be derived from the left side of the operator or from overhead.

There are so many trades in which spraying is successfully done that it is difficult to select any one as being of special interest. A simple operation is that of painting or repainting gas meters. In this case some parts of such work, as for instance the brass labels and name-plates, are not required to be painted. To protect them a mask of suitable shape is used. They are held in position by the stout wire appendage, and are readily put on and taken off. When it is desired to paint a very large surface, such as a gasometer, or a series of iron girders, or even a long stretch of fencing, it can best be done by using a portable spraying apparatus with motor sprayer and everything else required mounted on a platform or wheels, so that it may be moved along as the work proceeds.

An extremely interesting paint sprayer is that designed and used by the Pennsylvania Railroad. Mr. M. E. McDonnell, engineer, wrote: "The company does very little painting by dipping. The spray process is, however, used very extensively, a large percentage of our freight cars having been painted by this method for years. The method is very satisfactory and also economical. The saving in the cost of labour in the spraying method is approximately 60 per cent. In some cases the saving is greater than this. In one of our largest shops the cost of application per unit for a given number of square feet is $38\frac{9}{10}$ cents with the spray, as compared with $1 with brush. It might be said that more paint is applied per coating when the brush is used. A given surface which would require 10 gallons of paint for one coat by the brush method would require approximately 7 gallons by the spray method. When painting a freight car a more uniform coating is obtained when the brush is used, due to the fact that the paint can be brushed out behind ladders and other things which would obstruct spraying, while in the application of the paint with a sprayer it is necessary to apply a thicker coating at certain points in order to reach other points which are obstructed, and which must, therefore, be approached from a side angle. The spray, however, reaches certain crevices which cannot be reached with the brush, and this is in some cases advantageous with the painting of freight equipment cars. Our company would not consider returning to the brush method of painting." I may add to these remarks that, rapid as the increase in the use of paint spraying has been of late in this country, I am convinced that there is an enormous field yet untouched, particularly in connection with portable apparatus.

Turning from comparatively rough work for a moment to the most artistic, it need hardly be said that paint spraying may be employed for the most delicate artistic work, from retouching photographs to designs on pretty well any material.

As to the best paint for use in dipping and spraying, I need only say that ordinary paint will not answer, as a rule, because it is not of the right consistency. Supplies should be obtained ready for use or ready to be thinned by the addition of turpentine or white spirit from firms who have made a special study of the subject.

A few words now as to the method of painting or enamelling very small articles such as hooks and eyes, small castings and parts; no better method is known to me than the use of the "tumbler," which in form is similar to an ordinary churn. Inside this machine are placed a number of shot or steel balls of different sizes. The articles to be treated are then introduced, together with the japan, and the machine is started at varying degrees of speed. The shot carries the japan over the various parts and into the interstices. As different objects and materials require different speeds, some work will be started slowly and the speed increased to get the desired finish. The objects are then dumped out on to wire screens or baskets, and shaken, when the steel balls and shot fall through the mesh, leaving the articles that have been japanned behind. The baskets are then hung in baking ovens while the balls are washed in gasoline ready for use.

In order to obtain the exact amount of japan required for a given quantity of articles, the weight is taken of such articles, of the steel balls, and of the japan. After a little experimenting the proportions may be formed which will result in all parts of the articles being covered with japan without leaving any surplus whatever.

It need hardly be said that the subject of painting shells inside and out is of great interest in these days. The paint or varnish is applied to prevent the shell rusting, and the constituents of both materials are usually settled by the War Office specifications which, however, vary considerably. White lead must not be used for the paint; zinc oxide is usually preferred, and this may be followed by yellow ochre or other earth colours, or lampblack may be mixed with the zinc oxide to produce grey. The varnish is usually fairly cheap copal, which can be stoved or baked at a heat up to 300° Fah. The painting outside can be done by dipping by the aid of suitable mechanism, but the varnishing of the inside surface is more difficult. A brush or swab is sometimes used. The simplest plan is to place the shell upside down over a vertical rod communicating with the force pump. A single plunge will send the varnish to the upper end and the inside of the shell, the varnish runs off back into the tank and the shell is then removed and placed on an adjacent perforated table to drain. Another practical method is to use an ordinary spraying machine with an extension which reaches all parts of the interior. This method is employed at the present time in many munition factories. Shellac spirit varnish is often used for small shells, and this should be slightly warmed as well as

* Slides showing the various forms of apparatus were shown.

the shell itself into which the shellac may be poured and then be inverted to drain.

In a machine which is made by the Spray Engineering Company, of Boston, Massachusetts, U.S.A., an ingenious device is provided for admitting only a fixed amount of coating material at each operation. The exact amount is ascertained, the mechanism is then set to repeat precisely the same quantity, and the machine once so adjusted can be worked by an unskilled operator. The actual spraying is practically instantaneous, so that the speed is determined by the rate at which the shells are fed to and taken from the machine. What is known as Type A machine has a speed of 40 miles per minute. The standard machine consists of a table with steel-supporting frame, the operating mechanism being mounted beneath the table top. The usual coating material, such as varnish, asphaltum, paint, and similar special compounds, is carried in a reservoir supported above the operating table. The liquid coating material passes down the hollow reservoir support to an adjustable measuring device controlling the amount of material sprayed at each operation. A system of levers controls the motion of the device which cuts off the supply from the reservoir and admits the measured quantity of material to a channel leading to the spray nozzle. The last part of this motion admits a compressed-air supply which drives the coating material through the spray nozzle and distributes it evenly over the surface to be coated. High working speed is thus obtained without waste of material, and one setting of the measuring device ensures the delivery of a fixed quantity of coating material to each shell. The actual operation of discharging the varnish or other compound is effected by operating a foot lever.

Type B machine is adapted for coating uniformly the interior of deep shells from 3in. to 6in. diam., as well as cartridge cases for the various types of shells not exceeding, approximately, 3in. diam. One feature of the machine is a moving nozzle automatically controlled. The coatings are applied to the article while in a stationary vertical position.

Type C machine is designed for coating the outside of shells and cartridge cases not exceeding, approximately, 3in. diam. It is equipped with a motor-driven rotating shell table, also an exhaust fan mounted in a sheet-metal hood for protecting the operator from the paint fumes. The coating is applied while the shell is being rotated in a vertical position.

Type D machine is designed for coating the inside of shells larger than 6in. diam., and of those that are too heavy and too long to be handled in a vertical position. A motor drive is included for rotating the shell, also an exhaust fan as noted under Type C machine. The shell is laid on its side and rotated in a horizontal position during the coating operation. The nozzle, while spraying, is moved automatically along the shell axis, thus ensuring the uniform coating over the entire inside surface.

It is important to observe that before paint or varnish is applied it is essential that the surface be absolutely clean and free from grease. With this object the shells are boiled in a solution of caustic soda, and they are then thoroughly washed in clean water. Any shells which have been improperly varnished are boiled for as long as three hours, which is sufficient to remove the varnish and render the shells ready for treatment again.

In conclusion, I should like to refer to the most up-to-date method of painting the bodies of motor-cars. The method is extraordinarily quick, a coat of japan being given to a 4-seated car in exactly two minutes. This is done by discharging japan through a flexible tube connected with an overhead tank through a wide nozzle, which is opened by the pressure of the thumb and closed by a spring. The motor body is placed on a bogey with a trough-like tank on three sides of it and a solid iron sheet on the fourth side. On pressing the lever the japan literally pours out of the nozzle on to the work, and it is only necessary to move it very quickly in order to get the whole of the surface covered in the time named. Of course, a great deal more japan passes into the trough-like tank than goes on to the body, but this passes through a screen, and descends into a small tank below, whence it is pumped up to the elevated tank for use again. A few minutes are given for all superfluous japan to run off, and the bogey is then wheeled over to the stove where the body is placed for some hours until the coat is sufficiently hard to enable it to be rubbed down and then to receive a second coat in the same way.

A somewhat similar but improved method of painting motor bodies is largely used in America and is known as the "Aeron." In this process the paint, japan, or varnish is forced through a flexible tube, and is discharged continuously through a wide flat nozzle. A trough-like tank is provided into which the superfluous japan flows, but sufficient sticks to the surface to give a good thick and durable coating. In order to prevent the inside of the body being splattered with japan a brush is first used to apply it to the top edges and then the nozzle is passed rapidly over the surface on to which it discharges the japan. The superfluous material which flows into the tank passes through a filter and is used again, being continuously added to that in use. The body is allowed to drip for some minutes, and is then placed in a drying oven specially for the purpose to exclude humidity. The varnish coat dries in rather over four hours and may then be rubbed down lightly either with fine steel wool or pumice stone, when it is ready to receive another coat.

I am indebted to the "Iron Age," of New York, for the following details of the process of finishing an aluminium body, for it will be understood that nearly the whole of the materials for the undercoats are applied by means of the "Aeron." The aluminium body is first washed with gasoline applied with a brush, and this is wiped off and allowed to dry. A coat of oxide of iron priming and linseed oil is then given by means of an ordinary sprayer or air brush, and the body is then placed in a stove at 115° Fah. for three hours. It is then ready to receive a coat of coach putty, which is applied by hand, the object being to obtain a level surface. This dries in the air for 12 hours. Then a coat of half white lead and half rough stuff is sprayed on, and the body is stoved at 115° Fah. for three hours. The next process is to spray on four coats of rough stuff and to stove each at the same heat for two hours each. Next is applied by hand a coat of rubbing rough-stuff, which is air dried and then rubbed down with pumice stone. Some additional puttying is then usually required. The body is now in a condition to receive the first coat of colour, which is sprayed on, and this is allowed to dry in the air for six hours. The "Aeron," or flowing machine, is then employed to put on three coats of colour and varnish or enamel, the first two being stoved at 120° Fah. for four hours, and the last at 125° Fah. for four and a half hours A coat of rubbing varnish is then applied, and this is rubbed down with finely powdered pumice stone applied by means of a felt pad moistened in water. A final washing off with clean water and the body is ready for the finishing coat of varnish, which is applied by experts with the usual form of flat varnish brush. The body is then complete, and provided that good materials have been used, shows up with that brilliant finish which is so much admired.

Although there appears to be a large number of coats necessary for obtaining the beautiful finish there are, as a fact, fewer than would be required by the old process of applying all the coats by hand. By using the methods described, not only is a great saving of time effected, but the appearance of the finish is improved, while, more important still, the durability is distinctly increased.

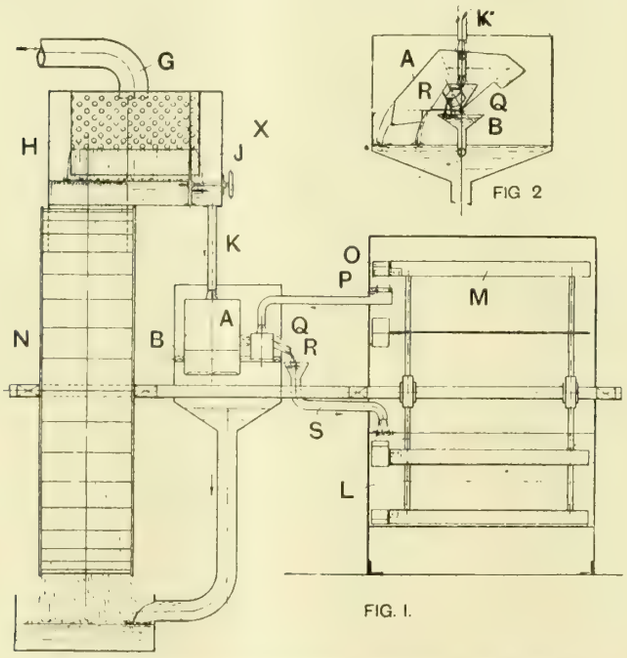
In conclusion, I desire to emphasize two important provisions which are absolutely essential to a good finish and speedy work. The first is to provide a room in which the paint and varnish is applied that is well ventilated, free from draughts, and is kept at a uniform temperature. But, above all, dust must be absent and the greatest care be taken to exclude it. I have seen painting shops adjacent to the joinery works with but little division between the two. The result, of course, is that specks innumerable settle upon the work, and the finish is spoiled. I would repeat, then, that too much care cannot be taken to eliminate dust. The second provision is a drying-room, which will facilitate the drying and exclude moisture.

PATERSON WATER-SOFTENING AND PURIFYING APPARATUS.

SOME improvements have been made and patented by Mr. Wm. Paterson, India House, Kingsway, London, W.C., in connection with water softening and purifying apparatus of the type in which means are provided for by-passing a predetermined or controllable proportion of the total flow to a measuring device adapted to operate the chemical supply during the continued operation of the plant. The improvements relate to the arrangements provided for distributing the chemical reagent or reagents to the water to be treated whereby the difficulties hitherto experienced in distributing the exact amount of reagent necessary will, it is claimed, be entirely obviated.

The apparatus, which is shown in the accompanying illustrations, is fitted with a double compartment oscillating receiver A, which is mounted upon a shaft B, the receiver being provided with a lever C (Fig. 5) adapted to move with the receiver and to operate either end of a double-ended ram, the two cylinders D of which are mounted in a stationary framing E and are connected together by a pipe F with an adjustable restricted opening into each cylinder so that as the tipping vessel A falls to one side one of the rams is operated so that the liquid within its cylinder is forced therefrom to the cylinder of the other ram through the connecting pipe F.

In the apparatus illustrated diagrammatically in Fig. 1 the water to be treated enters, by the pipe G, the tank or receiver H, which is provided with a perforated plate to steady



PATERSON WATER-SOFTENING AND PURIFYING APPARATUS.

the flow, and in front of this plate is arranged a weir X over which the water flows, and from this stream of water a controllable proportion of the incoming water is by-passed by an adjustable divider J through the pipe K to the movable receiver A, in connection with which is provided the receptacle L for the chemical reagent. The contents of the container L are kept thoroughly stirred and continually agitated by means of a series of rotating paddles M adapted to be operated by a water wheel N. On the periphery of the rotating paddle wheel is a plurality of cups O which are adapted to be filled with reagent during their rotation and to discharge the same into a receptacle P connected to a double compartment oscillating measuring vessel Q similar to that which is employed for measuring the water and situated outside of the reagent container L. This vessel is so arranged that one compartment at a time is in a position for being filled with reagent discharged from the measuring cups, and means are provided for maintaining the compartment full until such time as it is to be discharged into the water to be treated, as for example, the vessel Q may be provided with an outlet R through which the surplus reagent delivered to the vessel is allowed to overflow from the measuring device and through a chute S back into the reagent container L. The outlet device R is so arranged that it is adjustable as to level by being slidably or otherwise adjustably mounted upon the measuring vessel Q, so that the level of overflow may be adjusted in order to vary the chemical supply in any manner that may be desired.

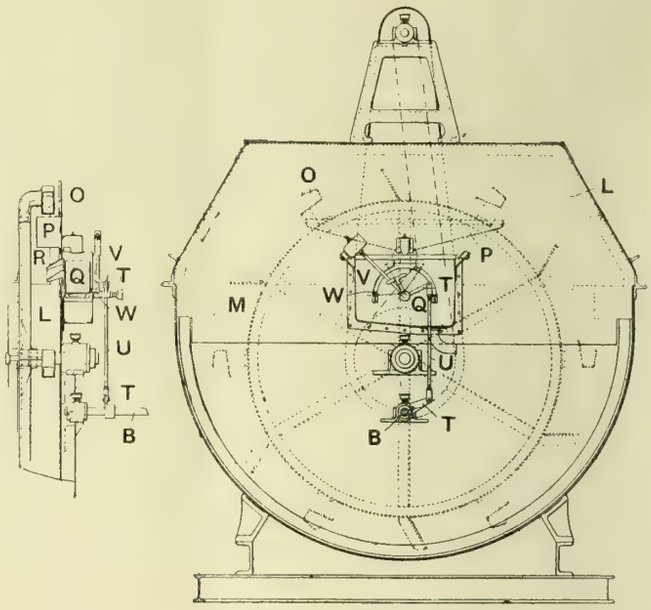


FIG. 4. FIG. 3.
PATERSON WATER-SOFTENING AND PURIFYING APPARATUS.

It is necessary that the chemical measuring bucket or container Q must always discharge the precise weight of chemical required to treat a predetermined weight of water, and in consequence it is necessary that the arrangement should be such that the chemical container instantaneously discharges its contents as the contents of the water-measuring device are discharged, as otherwise the excess reagent delivered to the measuring vessel would be delivered to the water to be treated. One method of attaining this object is illustrated in Figs. 3 and 4, according to which the chemical measuring device Q is connected with the water-measuring device by means of levers T and linkage U arranged to operate a loosely mounted weighted lever V. During the first part of the movement of

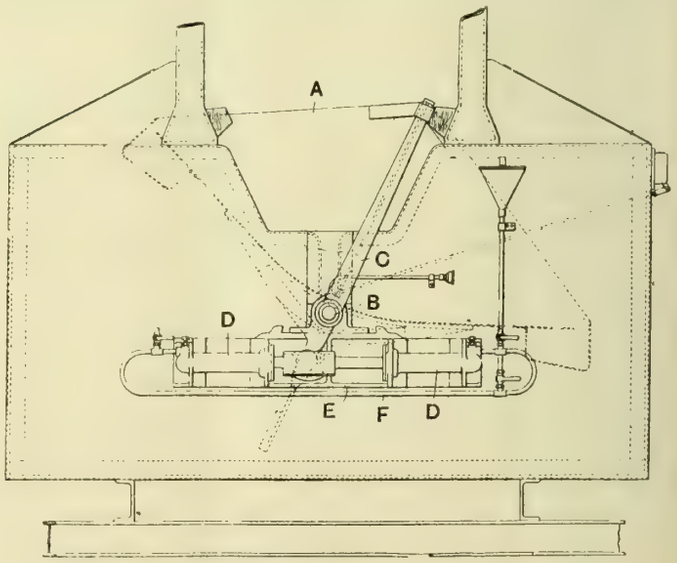


FIG. 5.
PATERSON WATER-SOFTENING AND PURIFYING APPARATUS.

the water-tipping vessel the lever is moved into a vertical position whereupon after passing the centre it falls of its own weight striking against a projection W upon the chemical measuring vessel thus instantly tipping the latter to discharge the contents of the full compartment into the water to be treated and to bring the empty compartment into the position for filling.

SANDBLASTING AND SANDBLAST MACHINES.*

BY J. J. RICHARDSON.

In the year 1870, the sandblast process was invented by Mr. Benjamin Chew Tilghman, of Philadelphia, who really borrowed, or adopted from nature herself, inasmuch as he intensified and put to use a natural force, the effects of which are always apparent under favouring conditions; that is to say, wherever we find large deposits of loose sand exposed to prevalent winds, by which the sand is caught up and blown against any hard substance, such, for example, as the glass in a window, the surface soon becomes depolished and obscured by the contact of the sand; or stone, the surface of which with time is sensibly roughened and sometimes scored in a manner quite distinct from ordinary weathering. The original patent specification stated that the process was for cutting, boring, grinding, dressing, pulverising, and engraving stone, metal, glass, wood, and other hard or solid substances by means of a stream of sand or other suitable material used as projectiles artificially driven against them by any suitable means of propulsion. The invention, therefore, stated shortly, consists of a stream of sand or other abrasive material, usually dry, but sometimes mixed with water projected with more or less force and velocity to strike and pulverise the surfaces of glass, stone, metal, and other materials upon which it is directed.

The abrasives used in the process include ordinary inland silicious sand, sharp builders' sand, powdered glass, emery from fine to coarse, chilled iron sand, and steel shot, and the streams of these, what we might term sandblasting mediums, are forcibly projected through variously formed nozzles, by means of steam, by currents induced by exhaust air or compressed air. Sand is greatly used for many purposes, but for cleaning the scale and core sand from iron, steel, and brass castings, chilled iron shot or grit is more generally used on account of its greater efficiency, not breaking up as the sand does on impact with the article being sandblasted.

Grains of sand have numerous angles, and the action of these grains (as also that of the other abrasives mentioned) upon the surface of glass, stone, or metal, is due to the circumstance that every individual grain in the incessant infinite number in the stream urged violently forward, has all its energy instantly arrested, transferred and concentrated upon its point of impact, where it produces a minute pit or depression; and as every grain in the shower acts alike, the abrasion resulting from the whole is perfectly uniform in depth, and texture or roughness. The action, moreover, is extremely rapid; a momentary application depolishes glass over any space that can be covered by one stroke of the sand shower, instantly changing the previous bright surface to obscured. A little longer exposure cuts more deeply and with further time apertures are readily pierced through sheet or plate glass.

Stone, marble, slate, and granite are equally amenable to its action. Iron, steel, and other metals have their surfaces easily reduced, and smoothly or coarsely granulated, according to the force and abrasive used, but all these materials being less brittle than glass take rather longer time. Speaking generally, the harder or more dense the material acted upon, the more rapid the cutting action, especially so when the velocity of the sand stream is increased. If fine granulation is needed, then finer abrasive material is used, and the air or steam pressure reduced.

Messrs. Tilghman's Patent Sand Blast Company, Ltd., Broadheath, near Manchester, are the original patentees and manufacturers of sandblast apparatus in this country, and the late Mr. J. E. Mathewson was continually bringing out new specialities in this line, and taking out master patents in this connection, for adapting the process to new purposes which the industries of the world demand. Mr. A. E. Mathewson, son of the above and the present managing director of the concern, has kept this forward movement going with equal zeal. This continued progress and the valuable experience thus acquired puts the company in a pre-eminent position to make and supply apparatus of the most improved form and greatest efficiency.

The sandblast process was first used in connection with glass marking and obscuring, and is to day largely employed in the glass trade. In using the process for engraving, lettering, or perforating glass, stone, &c., the parts of the surface which are not to be acted upon by the sandblast are protected by various elastic and tenacious substances, varying in thickness and durability, according to the depth of the cutting required and the brittleness of the material under operation. The more elastic this protecting substance, the less will be the impression made upon it by the sandblast. For engraving table glass, bottles, gas and lamp globes and chimneys, and small articles in sheet glass, a stencil is usually made of thin sheet iron or steel, worked to the proper shape and fitted on the article during the operation; these stencils with care last a good time and about 2,000 impressions can be made with one stencil. For engraving advertising tablets, door panels, and sheet glass, an elastic adhesive material is pressed upon the glass through a tinfoil stencil. For better class of work the glass is covered with prepared paper, upon which the design is sketched and then cut out by hand.

The sandblast process is also applied to the cleansing and finishing of new files, and is now found in nearly all the large file works in the country. Files scoured by this process after cutting and hardening are so thoroughly free from scale, salt, &c., that it is only necessary to rinse them in fresh lime water, after which they may be at once dried out and oiled; a great number of file manufacturers, in addition to scouring their files by this process, also sharpen them afterwards in another machine, which is somewhat similar.

In the sharpening of new files and resharpening of worn files the process consists of a stream of very fine sand and water, in the state of fluid mud (a liquid grindstone, in fact), directed at a certain angle with the face of the file, and driven with great velocity by jets of steam against the back of the teeth, the effect of which is to grind away the metal thereat until sharp points or edges are produced. By this means a file which has been fairly worn in the fitting shop can be resharpened by the sandblast so as to cut equal to a new file, and this operation can be repeated until the teeth are nearly worn away. This method of resharpening the teeth of files has been in use for some years, and has generally proved itself to be a valuable addition to the fitting-shop equipment. It must be understood that the process cannot replace broken teeth, or solidify those which have been honeycombed by rust, or raise new ones from the stumps of those worn down to the roots by scraping and fettling castings.

In order to prolong the life of a file by the use of this method, it should be treated in the same way as other edge tools are treated which are capable of being resharpened—sent to be touched up whenever they begin to drag or lose their smoothness of cutting. In this way, by repeated sharpenings, a file can be made to do several times as much work; beside which the fitter, having always sharp tools to work with, can do an increased amount of work with less exertion.

In the metal trades the sandblast is used for the removal of the hard scale so destructive to cutting tools from castings, forgings, stampings, &c. Also for the removal of the scale from sheet iron and steel prior to enamelling, galvanising, nickelling, tinning, &c., the cleaning of tubes and brazed joints, largely used in cycle work, and the reduction to clean metal surfaces of larger works ranging from the steel forgings of safes to armour plates. Among other purposes it is employed for removing fur and deposits in tubes and tanks, for cleaning off the paint and dirt within iron ships, for roughening the surface of metal rollers, for cleaning off the grime from stone, granite, and brick buildings. For large work in metal, say for the removal of scale from the heaviest of armour plates, it is generally necessary to take the sandblast to the work instead of the work to the apparatus, and this is when the portable plant is used, as also for cleaning the ends of electric tram rails before welding in site, &c.

I will now describe as far as possible the plants of the fixed types as used in the metal trades. In fettling and cleaning castings very considerable saving is effected by the use of the sandblast process, and no foundry, whether turning out small or large castings, should be without a sandblast plant. In the

* Abstract of paper read before the Birmingham Association of Mechanical Engineers.

cleaning of the castings a saving of at least 50 per cent. can be made in the fettler's wages alone. In the cleaning of steel forgings and castings which are now being so largely used, the sandblast is absolutely essential, as it is impossible to remove the scale and burnt-on core by any other means and leave a chemically clean surface. The benefits of having castings and forgings freed from scale and sand are particularly noticeable in the machining and finishing of same and where, as is very generally the case, expensive gang cutters are used, the saving in these tools alone amounts to very considerable sums, so large in fact as to very soon pay for the cost of complete plant.

Sandblasting machines for fettling or cleaning castings are of various types, but they are only very briefly divided as fixed and portable, the former vastly predominating. In each classification a number of designs occur. The fixed machines include tumbling barrels, rotating tables, and reciprocating tables, and closed cleaning chambers. These latter are arranged for the operator to work either inside or outside.

The regular sandblast apparatus for cleaning large castings comprises the apparatus, the air compressor and receiver, the sandblast room, the exhauster for returning the sandblasting medium to the apparatus for use over and over again, and the air washing arrangement. The essential blasting mechanism comprises a cylindrical casing, into which the sandblasting medium is fed. It is divided generally into two chambers, fed in the first place through the upper, then passing into the lower one under the control of a lever operating a sand valve under the upper hopper. From the lower hopper the sandblasting medium is allowed to pass through a slot, the opening of which is uncovered by a valve operated by a lever on the outside. It is then caught by the current of moving air and driven through the pipe to which the discharge nozzles are attached. Apparatus can be fitted with one, two, or even more nozzles as may be necessary. The air compressor provides a pressure of from 5lbs. to 25lbs. per square inch, and the receiver carries an even pressure free from the pulsations of the compressor.

The sandblast room is built of sheet iron on angle irons, and is provided with doors, a glass roof with ventilators in same, perforated steel floor and grids. After use the sandblasting medium falls through the grids into the hopper below, whence it is drawn by the exhauster through pipes into the top of the sandblast apparatus. The exhauster fan produces a vacuum of about 4in. water gauge, and changes the contents of the room four times a minute. This form of elevation automatically operating saves much labour, otherwise necessary. A cyclone separator occupies the upper portion of the apparatus, and this carries away the dust and finest core sand, leaving the heavier core sand and sandblasting medium to fall down through an air sieve, which draws away all core sand which is useless for sandblasting, and allowing only the sandblasting medium proper to fall into the chamber below for re-use.

The air which enters the room through the ventilators in the roof passes through the floor grids, carrying the dust with it. A washing arrangement, by which the dust is reduced to mud, can be fitted, and it consists of a rose jet through which water is projected against the rotating blades of the exhauster. The water being thus sprayed catches the dust and passes through the pipe into the settling tank, placed in a convenient position, generally outside the building. The mud settles at the bottom and has to be cleaned out as it accumulates. These rooms can be built in almost any size, the smallest being 6ft. by 6ft. by 8ft. 3in. high, but any size can be built as required. This type of plant is used for cleaning castings from ½ cwt. each up to several tons weight. For very large castings, for which the larger rooms are used, rails can be laid into the rooms and the work run in on bogies. The operator works inside the chamber, directing the blast nozzle by hand to any portion of the casting. He is provided with a helmet to prevent the rebounding abrasive material from striking his face and also to prevent dust from getting into the lungs.

The principle of the sandblast tumbling barrel is a slowly rotating cylinder supported at its circumference on rollers, and into this cylinder the small castings or forgings are put and the lid fastened. The blast is directed through one or both ends of the cylinder against the articles placed therein. The slow rotary movement causes the castings, &c., to tumble over one another, thus continually bringing new faces under the action of the blast. The sand and dust escape through the perforation in the barrel into the barrel box, the sliding door of which is closed when working, and is drawn by the current of air through the pipe into the sandblast apparatus. The majority of barrels in use are of this type, but for large firms who have very considerable quantities of small similar castings to be dealt with, a continuous sandblast barrel is made. This barrel is of the open-ended type. The body or cylinder is hooped with rings, which run on rollers that are driven slowly from a pulley through worm gears. The castings are fed into a hopper at one end and travel slowly through the barrel to the other end, where they are discharged upon a sloping grate During the passage they are subjected to the actions of four or more sandblast jets equally distributed along the length of the barrel.

The sloping grate is partly enclosed in an exhaust chamber and partly in a hopper below. In the chamber the sandblasting medium, scale, and dust are separated from the castings and drawn through a horizontal pipe into the apparatus and dealt with in the same manner as before described. This type of barrel can be continually fed and will clean thoroughly very large quantities of castings per hour. By maintaining a partial vacuum in the barrels all leakage is inward, thus entirely preventing any dust.

The advantage of the sandblast barrel over the ordinary rattler are: (1) First and foremost the work done, whether it be castings, forgings, or stampings, is absolutely clean and free from sand and scale, whereas in an ordinary rattler it is not. (2) The work being done by the impact of grains of sand, travelling at a high velocity, no portion of the surface of the castings can escape the blast, not even intricate cores. (3) In consequence of the slow revolutions of the barrel (about four turns only per minute), and the shortness of the operation (10 to 40 minutes), the sharp outlines of the work are perfectly preserved. (4) One sandblast barrel will do as much work as several rattlers, thereby saving considerable floor space. (5) The operation is entirely free from dust.

Sandblast machines are also made which consist of a rotating horizontal grid table, on which the articles to be sandblasted are placed; the sandblast jet is suspended above this table and gently swayed so as to cover the whole surface of the table. These machines are not, however, largely used, as they are generally only suitable for surface work on castings which have no cores to speak of.

Such work as the cleaning of the brazed joints of cycle frames, handle-bars, &c., casements, cleaning cutters, twist drills, hardened steel parts, motor-cycle cylinders, frosting the inside of cigarette cases before gilding, frosting such things as carburetter bodies before plating, is done in sandblast chambers. These are made in both circular and rectangular form, and vary in size according to the work required to be done in same; the operator stands outside the chamber, passes his arms through suitable openings, directing the blast on the articles to be cleaned, and observing the results through the window in front of which he stands. This plant is either provided with the sand and dust separating apparatus already mentioned, or for small work as a finishing operation the chamber is often placed over a simple type of apparatus without this separating arrangement.

Special types of sandblast machines are made for many purposes, amongst these being those for cleaning the inside of shells, the smaller shells up to 4·5in. being dealt with by a machine in which a fixed vertical blast is fitted, the nozzle being central and the shell being supported over it in a suitable holder, with ball and socket joint, so that the shell can both be turned round and also rocked sideways in order that the blast may reach the whole of the interior surface.

The chamber type of machine is also used for cleaning shells of this same size; the shells in each case, however, are horizontal and are passed through from side to side of the chamber by means of small doors. The blast jet is brought into position opposite the open ends of the shells, the operator standing in front of the chamber with his hands through the opening provided, watching the operations by means of the window.

Larger shells are cleaned in the sandblast room previously described for castings, and are dealt with very quickly, being passed through the room on a table or bench running the whole width of the room. The shells are rolled through doors on to the bench and out at the opposite end. The operator in this case works inside the room, wearing a helmet to protect his face and lungs, the blast being directed by hand. By using a trolley run into the room, shells of the largest size can be treated.

Another type of special plant for this purpose is that for cleaning cast or forged steel shells before and after machining. This plant consists of a machine in the form of a bench with a revolving table mounted on a suitable base, which is carried on girders on legs to bring the base to suitable height from floor for convenience in working. The baseplate is provided with a machined ball race for carrying the gear-driven revolving table upon which the shells are mounted in suitable die plates, and thus given a movement of rotation. In order to reach the whole of the interior of the shell, suitable gear for operating the blast jet is secured underneath the baseplate, and this gear imparts to the jet a swinging and lifting motion obtained from hand levers at the side. Underneath the baseplate a sheet-iron hopper is provided for collecting the sand, snot, dust, &c., and from which it is drawn to the separating chamber of the sandblast apparatus.

METALLURGY OF THE RARER METALS.

In the course of a paper on "The Metallurgy of the Rarer Metals," read at a recent meeting of the American Institute of Chemical Engineers, Prof. J. W. Richards stated that there were many metals which might be called the rarer metals, but the most interesting among these, both to the metallurgist and economist, were those metals whose compounds were relatively cheap and which commanded high prices because of the difficulty of their reduction. These were metals whose market prices might at some time be reduced anywhere from one-half to nine-tenths by improved methods of reduction. He said that if his paper had been written 30 years ago, aluminium would be one of the metals that would be discussed, being in 1886 one of the rarer metals selling at £2 per pound. The silicon industry furnished another example of great reduction in the cost of the metal. This, in 1900, was selling as a chemical curiosity at over £20 an ounce; now 5d. per pound was a good market price for it.

The author referred at length to the number of metals that at present command high prices, but which by improved metallurgical processes might be made very cheaply. These include beryllium, boron, magnesium, calcium, strontium, zirconium, molybdenum, barium, titanium, chromium, and cerium (mixed metals of the cerium group). He said the present methods of reducing beryllium were tedious and costly and that it was not to be expected that this metal could be made cheaply until some one mastered the direct electrolysis of the oxide, dissolved or suspended in a more stable melted salt, which was by no means an impossibility. He said this metal, being white, malleable, and unchanged in air, with a specific gravity of 1·64, would make it particularly useful for objects where great lightness and permanence in air were the first consideration, with the cost secondary. He characterised it as a metal that would repay extended metallurgical research and minute physical and chemical study of its many unique properties.

According to Prof. Richards the metallurgist had not made a fraction of the progress that he should have made with magnesium. Although magnesium oxide cost only a few cents per pound the metal sold for about as many dollars per pound, and was scarce. But he believed that by improving the methods the reduction of magnesium could be produced at 1s. per pound. He said that while the war continued, with its enormous demand for magnesium for military purposes, the price would remain high, but with improved processes that were being developed he believed that after the close of the war, with normal industrial conditions, magnesium would sell at a price which would take it out of the class of rarer metals and put it among the common ones. As the price went down its industrial uses would increase in geometrical proportion, and instead of the production being expressed in thousands of pounds per year it would reach thousands of tons. This would be one of the by products of the war's stimulus to metallurgical industry.

The possibilities held out to the metal industry by reasonably cheap magnesium were, he said, extremely interesting. It was quite possible that alloys analogous to dur-alumin might be discovered, as strong as soft steel with only 30 per cent. of its weight, which would find extensive use in aeroplanes and dirigibles. Such alloys might largely displace aluminium alloys, which were now used by the thousands of tons annually in the automobile industry, with a saving of one-third in weight which would compensate for the higher first cost. He predicted that the metallurgical use of magnesium would also be greatly extended by its lower price, such as for deoxidising brass, copper, bronze, nickel, and monel metal, since it was a much stronger deoxidiser than aluminium. In fact, aluminium had blazed the way into numerous uses for which magnesium, as soon as it became cheaper, would compete, and replace its older sister. He predicted a large future for magnesium as one of the common metals of every-day life.

Calcium, strontium, and barium were referred to as the trio of highly interesting elements, common enough in nature but scarce and of high price because of the metallurgical lack of efficient and cheap methods of reduction. Calcium was referred to at present as a semi-rare metal which could be produced much cheaper by present methods if made on a large scale to fill a large demand. The principal trouble at present was in finding uses for the large production. He said its possible alloys with other light metals should be exhaustively studied, and that another large possible use was as a chemical purifying agent in melting and casting metals. A small addition of metallic calcium might be used to reduce the amount of sulphur and phosphorus in steel, and other metals and alloys whose properties were damaged by sulphur or phosphorus might be similarly refined or improved. Barium was referred to as a metal that could be obtained in large quantities if its uses were developed. As barium was a good conductor, its use was suggested for electrical contrivance, and there were possibilities that its cost could be very materially reduced.

The fact that the use of chromium in steel was rapidly extending to all varieties of extra hard and high-speed steel was referred to, and the author stated that the use of pure chromium was limited by its high cost of production and our lack of knowledge as to how to handle it and its possible useful effects. For example, chromium electro-plating was white and durable, and for many purposes might be superior to nickel and almost equal to platinum plating, but the technique of always getting perfect plating had not been mastered.

Ferrochromium alloy carrying high carbon (6 to 8 per cent.) was produced cheaply in crucibles, cupola furnaces, blastfurnaces, and electric furnaces. Low-carbon ferrochromium commanded three to five times as high a price because of the difficulty of decarbonising the raw product. The author hoped that a test would be made in the electric shaft furnace to see if it was not possible to produce directly from the ore a low-carbon product and said the present prices, £20 and £100 a ton respectively for the high and low alloys, would warrant a great effort in that direction.

The metallurgy of chromium was, in the author's opinion, full of attractive possibilities, and the usefulness of pure chromium in the field of alloys was only beginning to be scratched. The scratch, however, had proven very much worth while. The success of A. J. Rossi and the Titanium Alloy Mfg. Company in producing ferrotitanium alloy from the enormous quantities of titaniferous iron ore in Northern New York and Canada was referred to, and if uses were found for pure titanium, some other than electric furnaces must be used to reduce it. These methods of reducing pure titanium were, like its prospective uses, still in the future. The metal was now quoted at about the price of silver and if the problem was properly faced it could probably be made as cheap as chromium.

CONDENSER TUBE TROUBLES.*

BY A. E. WHITE.

AN investigation was conducted by the author in 1913 for the Edison Illuminating Company, Detroit, to (1) account for the splitting of brass condenser tubes in service; (2) determine the proper chemical composition, mechanical treatment, and heat treatment which should be given to the tubes; (3) formulate such specifications as would be of material service in the purchase of tubes. The specifications finally formulated completely eliminated the troubles previously encountered.

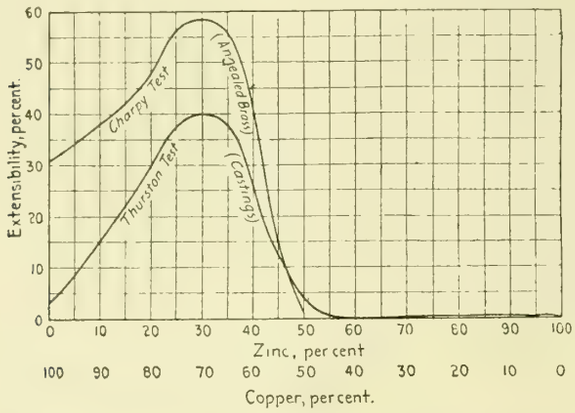


FIG. 1.
The maximum ductility of copper-zinc alloys is found to be at a mixture of 70 per cent. copper and 30 per cent. zinc.

Chemical analyses were made to determine whether or not the splitting was due to the presence of such impurities as antimony, bismuth, iron, &c. The analyses showed the tubes to be of fairly uniform composition, and to be made on a basis 60 per cent. copper and 40 per cent. zinc, corresponding to Muntz metal. The percentage of impurities found was exceedingly low and these could not be held responsible for the tube failures. Subsequent investigations discovered the cause of splitting to be faulty manufacture. Specifically, the faults were excessive pinching during drawing, insufficient annealing between drawings, or an omission of annealing or incomplete annealing after the final drawing.

For fresh, unpolluted water the best composition is believed to be 70 per cent. copper and 30 per cent. zinc. For salt or polluted water an Admiralty mixture, 70 per cent. copper, 29 per cent. zinc, and 1 per cent. tin, is especially good, as are mixtures of 80 per cent. copper, 20 per cent. zinc, and 90 per cent. copper, 10 per cent. zinc, respectively. For normal conditions, these latter three are expensive and may be disregarded.

The 70-30 mix is regarded as most desirable for the following reasons: (1) Such a proportion has the maximum ductility of all the brass compositions (see Fig. 1). (2) This mix gives a greater promise of adequate cold working and annealing. (3) The tube will have but one metallographic constituent, which will preclude the possibility of electrolytic action.

While a tube of 55 per cent. copper and 45 per cent. zinc has a greater tensile strength than one of the 70-30 composition, yet the greater ductility of the latter renders it superior for condenser use. Moreover, the tensile strength of the 70-30 tube is ample for the purpose for which it is used. In regard to working the tubes, the temptation is to work them hot as much as possible, this being less expensive than cold working. The very nature of the 70-30 metal precludes to some extent the tendency to hot working. Cold drawing, when not too severe, assures a breaking down of existing crystallisation, resulting in both smaller and better interlocked grains. It also makes necessary annealing between each set of cold drawings, both of which processess improve the quality of the tube. Too much cold drawings between annealings will distort the grain structure to such an extent as to produce heavy slip bands which are almost impossible to eliminate. It is more desirable to reduce the thickness of the tube by many light draughts than by a few heavy draughts. Not less than six drawings should be made, and 12 or even more cold drawings are to be preferred.

The following impurities have a bad effect on the quality of condenser tubes. They should be limited as follows:—

Lead.—If more than 0·1 per cent. lead is present the ductility of the tube may be impaired. Lead is detected by the microscope, appearing as black dots scattered at irregular intervals over the surface.

Arsenic and Antimony.—Antimony tends to cause cracks in the metal containing it. It is advisable to keep the arsenic and antimony under 0·02 and 0·002 per cent. respectively.

Bismuth.—The effect of bismuth is similar to that of antimony, although it is less injurious. It should be kept below 0·01 per cent.

Iron.—Iron will not have any appreciably harmful effect on the tube, providing it does not exceed 0·075 per cent.

The heat treatment of condenser tubes should consist in annealing each tube between each cold drawing or set of cold drawings, at a temperature high enough to remove the grain distortion caused by the cold drawing, but not at such a temperature as will permit crystalline growth to take place to such an extent as to cause coarse crystallisation. After the final drawing, each tube should be annealed just enough to break down the distorted structure produced by the last drawing. No specific temperatures can be given, as variations in the chemical composition and initial crystal size produce changes in the annealing temperature.

The correct annealing temperature of each composition should be ascertained by microscopic and physical test researches. Fig. 2 is a typical curve of such a research. The best annealing temperature is probably that at which the curve of tensile strength crosses that of percentage of elongation. The length of time the tube is held at the annealing temperature is also of importance. A Muntz metal tube of 60 per cent. copper and 40 per cent. zinc gave a maximum ductility when heated seven hours at between 560° C. and 690° C., while the same metal annealed for half an hour at 750° C. also attained maximum ductility. These temperatures are

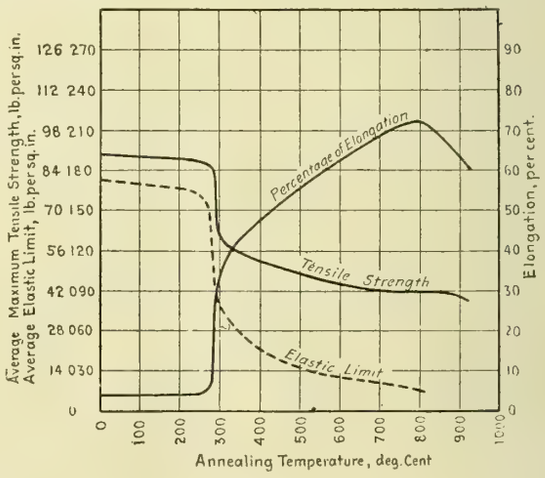


FIG. 2.
The best condenser tube as regards its physical properties is the one that combines maximum ductility with maximum strength, indicated by the crossing of the curves representing those properties. The above is a record of the annealing tests of a tube of 67 per cent. copper and 33 per cent. zinc.

too high for commercial work, as they produce an unnecessarily large grain. When tubes are heated to, but not held at, a given temperature and cooled at different rates, the metal which cooled the slowest lost its original structure the earliest and produced coarse crystallisation the quickest.

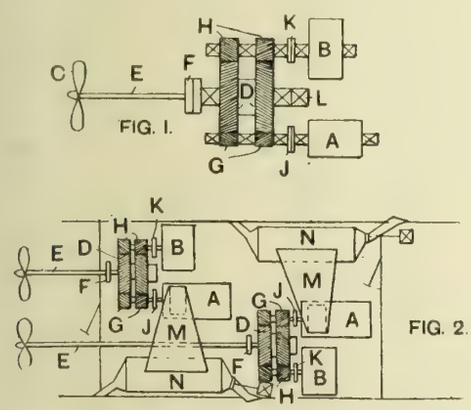
As a result of the investigation a set of specifications for condenser tubes was prepared. These conform somewhat closely to the U.S. Navy Department specifications but have had added a provision for microstructure examination.

* Abstract of paper read at the annual meeting of the American Society for Testing Materials, June 30th, 1916.

Thermit, Ltd.—This company has received a communication from the Public Trustee to the effect that he has entered into an agreement to sell the whole of the enemy shareholding in that company to the Birmingham Metal and Munitions Company, Ltd. The Thermit Company, Ltd., will continue to trade exactly in the same way as hitherto.

POWER PLANT FOR MARINE PROPULSION.

With a view to enable power plant on board ship to operate effectively and efficiently under widely varying operating and load conditions, the Westinghouse Machine Company, of East Pittsburg, Pennsylvania, have recently designed and patented the arrangements illustrated herewith. In the arrangement shown diagrammatically in Fig. 1 the apparatus comprises a steam turbine A, an electric motor B, which under certain conditions is capable of operating as a generator, a propeller C, and gearing between the propeller, the turbine, and the motor. The gearing is so arranged that the speed reduction between the turbine or engine and the propeller is different from that between the motor and the propeller. The gearing consists of a large gear D, the shaft of which is shown coupled to the shaft E of the propeller by means of a clutch F. The gearing D meshes with two pinions G and H of different diameters, the shaft of the smaller of which is shown directly connected to the shaft of the turbine by means of a clutch J. The shaft of the larger pinion H is shown directly connected to the shaft of the motor by means of a clutch K, and the shaft of the gear D is shown provided with a thrust bearing L for taking up the axial or longitudinal thrust of the propeller C. With this arrangement the propeller may be driven either by the turbine or by the motor, and in addition to this, the turbine may be employed in driving the motor while it is operating as the generator and is charging the storage batteries from which it receives current while driving the propeller independently of the turbine or in conjunction with it. While the turbine is driving the propeller independently of the motor B, the clutch K may be disengaged for the purpose



Power Plant for Marine Propulsion.

of uncoupling the motor from the pinion H, and the clutch J may be disengaged for the purpose of uncoupling the turbine from the pinion G when the motor is delivering power to the propeller. During the charging operation, or while the motor is operating as a generator, the clutch F may be disengaged, so that power will not be transmitted to the propeller by the gear D. With this arrangement of apparatus, the propeller may be driven by the turbine or motor operating independently of or in conjunction with each other, and the motor may either run idle or be converted into a generator while the turbine is delivering power to the propeller.

In Fig. 2 is shown an arrangement of apparatus, for use in connection with a vessel, having two propellers. The power developing or transmitting apparatus for each propeller is similar in some respects to the apparatus shown in Fig. 1, in that it includes a turbine or engine A, a motor B, and a transmission gearing between the turbine and the motor and between both of them and the propeller. The transmission gearing illustrated includes a large gear D which is coupled to the shaft E of the propeller by means of clutch mechanism F, and the gear D meshes with two pinions G and H of equal diameter. The shaft of the pinion H is shown coupled to the motor B by means of a clutch K, while the shaft of the pinion G is shown coupled to the shaft of the turbine A by means of a clutch J. The exhaust of the turbine communicates with an exhaust header M, which in turn communicates with a condenser N, in which the cooling water intake and the discharge project through the side of the vessel.

EXTRACTION, OR BLEEDER-TYPE, TURBINES.*

In looking up the history of the steam turbine, it is interesting to note the great advance in the economy as well as the capacity of this type of prime mover. In 1905, in a report of a committee on the steam turbine, consisting of Messrs. Eglin, Dunham, Moultrop, Cato, and Andrew, to the National Electric Light Association, held in New York City, they gave the number of turbines of the largest size in operation at that time as follows: Four 5,500 kw. machines, 10 5,000 kw. machines, with a total of all descriptions of 224 turbines with an aggregate capacity of 350,000 h.p. In 1905 the largest turbine designed to operate non-condensing was of 2,000 kw. capacity, running in a sugar refinery. The first large extraction-type turbine in operation was a 2,000 kw. unit in 1905. There are about 30 extraction-type turbines in operation at the present time.

Before considering the use of steam turbines for heating, drying, or other purposes requiring exhaust steam, a careful survey of all the conditions from every viewpoint should be made. The electrical and heat balance should be carefully studied not only from the present aspect of the case, but also the future development of the electric and heat loads, to determine as far as possible the approximate divergence of the respective loads. There is a point where a non-condensing unit would prove more economical, also a point where a condensing turbine should be installed and live steam used. As a general statement, an extraction turbine should be installed when it can carry the average load with the average amount of steam required for heating being extracted. Some of the limiting factors governing the maximum amount of steam to be rejected to the heating system are—the capacity of the turbine is reduced, the regulation is impaired, and the ability to handle momentary overloads is handicapped.

With an extraction turbine, as with a straight condensing turbine, the ability to handle overloads depends on the design of the unit. For instance, in a straight condensing machine, assume a water rate of 20lbs. per kilowatt on a 500 kw. machine. If the nozzles of the turbine were designed to pass only 10,000lbs. of steam, the machine would have no overload capacity, and if it is running at or near the full-load point, we cannot take much of a swing. In an extraction machine suppose it were designed to deliver 1,000 kw. load and a maximum of 30,000lbs. of steam—when giving this electrical load if we were extracting no steam we would have a great overload capacity on the electrical end, but if we were extracting 30,000lbs. and attempted to go above 30,000lbs. extraction we would have to relieve the turbine of some of the electrical load in order to have any overload capacity. In other words, it is merely designing the turbine liberally enough to carry the maximum load with a safe overload capacity on top of this. As the load on the turbine is the sum of the heating and electrical load, the heating load serving to take capacity off the machine the same as the electrical load does, it will act the same as any other equipment when overloaded on either end. The regulation should not be materially impaired unless we are running too close to the maximum on either the steam or electrical load.

We believe that the most common cause of dissatisfaction with the extraction-type machine is due to the fact that a man is unable to definitely determine the amount of steam he is taking to the heating system, and in many cases will attempt to extract more steam than the machine was designed for and be disappointed because the machine will not deliver its full electrical load as well. In other words, while he can readily determine by the meters on the switchboard when he is getting to the limit of the capacity on the electric end, there are usually no similar instruments on the extraction line to determine when he is reaching the limit on the steam end, so that it is possible to have his machine running practically at the maximum-load point considering the total steam and electrical load and not be aware of it until some sudden demand on the electrical end exceeds the capacity of the unit and makes itself known by a decrease in speed with a conse-

* Abstract of report of Station Operating Committee, presented at the eighth annual convention of the National District Heating Association, New York, May, 1916.

quent disturbance on the electrical system. It is found in practice that when a central station is furnishing power for large milling industries, &c., any variation in speed is immediately noticed in the operation and output of these mills. It is necessary, therefore, that sufficient generator capacity is in service at all times to provide for short circuits on exterior lines or momentary overloads.

A point can be reached where live steam must be admitted to the heating system or another unit placed in service. It is usually more economical to admit some live steam than to place the extra unit in service. This depends on the relative load factors. The economy of a turbine of this type as given by the manufacturers is usually the overall economy per kilowatt when extracting a certain amount of steam. But the actual percentage of the total heat admitted to the turbine used and the balance rejected to the heating system is not given.

Non-condensing turbines for heating purposes should be installed only when the average exhaust steam required equals or exceeds the electrical output of the unit. For hot-water heating a condensing unit designed to carry full load when running non-condensing has given satisfactory results. When properly installed, any required vacuum to maintain any necessary temperature can be obtained with a corresponding economy. In case of low steam due to boiler trouble, the turbine can be immediately operated condensing with maximum economy, thus protecting the electric load when otherwise both heating and electric loads might be lost. This point also applies to turbines of the extraction type.

On account of the extra boiler capacity required with non-condensing apparatus, it may be found that the extra fuel and maintenance required to bank fires during the non-heating season will pay the interest charges on the additional cost of the cheaper condensing system. And by using extraction or condensing turbines running non-condensing, depending on the amount of steam required for heating with relation to the size of turbine and its load, satisfactory results are attained.

In the design of a new plant complete, care should be used to arrange the system to be operated with as low a back pressure as possible, and the manufacturer of turbine apparatus should be fully acquainted with the pressures and amounts of steam required for heating. It might be that the extraction openings from the turbine could be taken from a point nearer the exhaust end of the machine by slightly lowering the pressure below that stated in the proposition as first placed before them. In other words, with an absolute stated pressure and load specified, it might compel them to extract the steam at a higher stage than necessary with lower economy. In this case a slight increase on investment in sizes of heating mains might be advisable, the increased economy of the unit serving to pay the additional interest charge in all the foregoing. (I am referring to plants having units of 500 kw. capacity and larger.)

The saving by using an extraction turbine is shown by a prominent turbine engineer by several examples which follow, and prove conclusively the economy of this type of apparatus and also the economy of keeping the extraction pressures as low as possible: First, the problem is supplying 22,000,000 B.T.U. per hour to the heating system and 1,000 kw. electrical energy. If we use a straight condensing turbine, it will be necessary to take steam direct from the boilers for the heating load, which would require for the amount of heat given 18,400lbs. of steam per hour. The electrical load would require 18,500lbs. of steam (18·5lbs. per kilowatt), or a total of 36,900lbs. of steam for the combined load. If an extraction turbine was used and it was necessary to extract at 15lbs. gauge pressure, the quality of the steam at the extraction opening of the turbine would be approximately 96½ per cent. dry, and it would then require 19,700lbs. of steam per hour to furnish 22,000,000 B.T.U. heat energy. The turbine would deliver this 19,700lbs. of steam at 15lbs. gauge back pressure and 1,000 kw. electrical energy for a total of 31,600lbs. of steam at the throttle, or a saving of 36,900lbs. minus 31,600lbs., or 5,300lbs. of steam per hour. Without the extraction turbine it would require 18,400lbs. of steam per hour for the heating system. Therefore the amount of steam chargeable for power would be 31,600lbs. minus 18,400lbs. (the equivalent of which goes to the heating system), leaving a balance of 13,200lbs., being at the rate of 13·2lbs. per kilowatt-hour chargeable to power. If we extract at 5lbs. pressure (quality 95·5 per cent.) owing to the slightly lower heat content, it would require 20,000lbs. of steam to furnish the 22,000,000 B.T.U. heat. Under this condition the turbine would deliver the 20,000lbs. of steam at 5lbs. pressure and deliver 1,000 kw. electrical load for a total of 28,900lbs. of steam at the throttle; 28,900lbs. minus 18,400lbs. (chargeable to heat) leaves a balance of 10,500lbs. chargeable to power, or 10·5lbs. per kilowatt-hour.

It will be observed from the foregoing calculations that all the saving is credited to the electrical department. As a matter of interest it should be noted in passing that this saving does not all accrue to the electrical department—in fact, it is questionable which department, steam or electric, should get the credit, or whether it should be divided between the two. One thing is certain—if an existing electric plant adds to its system a heating plant, this saving would be credited as an advantage to having a heating plant. If for matter of rates the cost of service in the two departments was to be considered, then this saving should be divided between the two departments somewhere in proportion to the steam requirements of each.

Under the foregoing figures (extracting steam at 15lbs. pressure) the saving of 5,300lbs. of steam should be divided between the heating and electrical operating costs in proportion to the steam requirements if each were operated separately. Of this saving $^{197}/_{369}$ would be allowed to the heating department and $^{172}/_{369}$ would be credited to the electrical department. In this paper this matter has not been considered. We have endeavoured only to show the saving and what it was, without consideration of what department would be affected.

It is evident from these calculations that extraction of steam from a turbine at 5lbs. back pressure for heating, has a decided advantage over extraction at 15lbs. back pressure, in (1) 3·5 per cent. more pounds of steam extracted into the heating system; (2) 25·2 per cent. decrease in the cost of producing 1,000 kw. Again, in the extraction against a back pressure of 15lbs. we have 6,600lbs. of steam that was used in producing part of the 1,000 kw. and again used in the heating system. And in the extraction against a back pressure of 5lbs. we have 9,600lbs. of steam that was used in producing part of the 1,000 kw. and again used in the heating system. Or an increase of the 5lbs. over the 15lbs. of 6,600÷9,600 equals 69; 100 − 69 = 31 per cent.; that is, 31 per cent. more steam is saved by extracting at a back pressure of 5lbs. than 15lbs.

We believe that the relative saving by operating under the lowest pressures is not thoroughly appreciated and that cases of improper installations and piping that impose a burden on any existing plant in increasing pressure to furnish satisfactory service to these isolated cases should be either corrected or eliminated entirely from the system. New business departments sometimes in their zeal to make a good showing, which, of course, is commendable, forget the advisability of taking on certain loads from an engineering standpoint. While diverting from the point under discussion, the writer cannot refrain from stating that the closer the relations are between the sales department and the engineering department, the better are the final results.

So far as the operation of this type of turbine is concerned, we can only say again that all piping must be of ample size for the increased amount of steam required, oil pumps and governing apparatus large enough to handle the additional regulating mechanisms, back pressure or check valves of sturdy design, properly tested at stated intervals, and kept in operative condition, especially when two or more units are in parallel. Also, when operating turbines in parallel with the exhaust from a reciprocating engine, the piping and regulating apparatus must be carefully arranged to avoid the pulsation from the exhaust which might start hunting in the turbine.

We believe more care should be given in the design of extraction turbines in the distribution of metal due to extra-

ordinary temperature and expansion strains, and that all valves and connections add to the difficulty of maintaining a vacuum with light loads when operating straight condensing. A point in favour of extraction turbines is the effect on the average load factor on the boiler plant. Experience has shown that sudden overlapping peak loads can be taken care of by simply changing the adjustment of the extraction valves, allowing more steam to be used condensing for a few minutes, saving the stand-by boiler losses in some cases.

The use of extraction turbines as compared with reciprocating engines for heating eliminates many sources of complaint and trouble. Experience shows that air vents require less attention, traps require less cleaning, and meters are more accurate, owing to the absence of oil in the steam. There is less odour from air vents. Variators and valves require less attention. There is less moisture in the steam, owing to absence of initial cylinder condensation. Diaphragm breakage due to filling up of lower parts of variators with caking oil and dirt has ceased entirely.

Radiation is more efficient because of the absence of oil, and the care and attention of oil separators, traps, &c., at the power house is not required. In a system having over 500,000 sq. ft. of steam radiation, with about 400 consumers, this system being about 20 years old, all leaks, meter readings, and troubles are taken care of by two men. This includes tests for pressures and other work foreign to legitimate maintenance and operation. The cost of cleaning apparatus decreased each year after the extraction turbine superseded the reciprocating units for heating. There have been no complaints traced to stoppage in pipes and fittings during the last year, and the steam is available in cooking processes in which the steam comes in direct contact with the material to be treated.

Labour costs at the power plant are less, as there is no oiling of engines and not so many parts to watch. A plant turning out from 900,000 kw. to 110,000 kw. per day with 300 miles of high tension lines, 60 miles of inter-urban railway, and 500,000 sq. ft. of heating is operated with one watch engineer and one oiler per shift in the engine room.

FUEL ECONOMY AT COLLIERIES.*

BY F. F. MAIRET.

A COMPARISON between the heat units utilised at an average colliery with those utilised at an economical modern steam plant, such as a generating station, shows in a striking manner the possibilities of economy in colliery steam production and utilisation. The writer from data in his possession puts the colliery result at 1·7 per cent. of the heat units produced from the fuel burnt, while at the generating station 8 to 9 per cent. are converted into work. The one result is less than one-fourth of the other. The conditions are so different that it is impossible that the same result can be attained at the colliery as at the modern steam plant, but some considerable leeway may be made up, and it is very largely to pointing out the losses which now occur in colliery plants that the writer has devoted the present paper. With the doubling of the wage bill the cost of all coal has more than doubled. It has, therefore, become urgent to turn into profit this coal hitherto lavishly burnt.

Steam Generation and Distribution.—Of the heat produced in colliery boilers only about 50 per cent. is absorbed in the water. This low efficiency is in part due to causes which would obtain under the most favourable conditions; but there are other losses which are attributable to special bad conditions which frequently exist at collieries. In a test from a battery of six Lancashire boilers, hand fired with fuel of 11,840 B.T.U. per pound, the balance shown in Table I. was arrived at.

With lower classes of fuel there is a tendency to increase the excess air—no doubt to force combustion. This could be attained by using heated air, preferably as dry as possible. Some makers of forced-draught apparatus claim a saving of from 15 to 25 per cent., but although the writer does not believe that these test results are maintained, there is little doubt that with the lower grades of fuel a greater saving even than this might be attained. On the other hand, a saving of 15 per cent. on low-grade fuel would not permit of the same capital outlay as on the same percentage of good coal; but in the case of a colliery all available unsaleable coal of a sufficient calorific value would be burnt, being merely supplemented as required by good coal, so that all savings up to a certain point would be saleable product.

TABLE I.

	B.T.U.	Per cent.		B.T.U.	Per cent.
1lb. of coal as fired, lower value	11,840	100	Heat lost in the products of combustion	1,575	13·3
			Heat lost due to excess air	1,960	16·6
			Heat lost in superheating and evaporating moisture in fuel	65	0·5
			Incomplete combustion	-	—
			Unburnt combustible in ashes	367	3·1
			Radiation—hot ashes; moisture in air and unburnt hydrocarbons.....	1,323	11·2
			Heat transferred to water	6,550	55·3
	11,840	100		11,840	100·0

DEDUCTIONS.

Heat transmitted per square foot of heating surface, per hour	3,580	B.T.U.
Weight of fuel per square foot of grate, per hour	15·1	lbs.
Water evaporated per pound of fuel as fired	6·06	,,
Equivalent from and at 212° Fah.	6·75	,,
Air used per pound of fuel as fired	22·6	,,
Air theoretically necessary for complete combustion	9·4	,,

Flue covers have been tried with a varying amount of success with the idea of preventing both the leakage of cold air and the radiation of heat. One of the best of these covers is the Lyddon pattern, having high non-conducting properties to air and heat, and being practically impervious to moisture. It is provided with a lip to receive the covering from the crown of the boiler, which ensures an airtight joint between the two. A plain statement of the actual loss in British thermal units does not always appeal to the steam user to the same extent as the actual loss in pounds of steam, coal, or £ s. d. A particular case in the mind of the writer is a range of 8in. internal diam. naked steam pipes conveying steam from the boilers to an engine 294ft. distant; with the temperature of 307 Fah., which corresponds to the steam pressure, the actual loss due to condensation is 1·5lbs. per run of pipe, and allowing 34 flanges each equal in surface to 1ft. in length of pipe; this represents 492lbs. of steam condensed in transit. With such boilers as obtain in the average colliery, viz., 50 per cent. efficiency, this represents 90lbs. of coal per hour.

The ideal material for non-conducting covering appears to be "slag-wool (or silicate-cotton)," both on account of its high non-conductive and non-inflammable properties. Silicate-cotton owes its non-conducting property to the fact that it encloses the greatest possible number of microscopic air spaces by refractory surfaces. At a recent investigation on behalf of the Bureau of Mines, U.S.A., it was found that with a non-conducting wall consisting of air space enclosed by two firebrick walls, while there was a considerable drop in temperature from one side of the firebrick wall to the other, the two adjacent surfaces thereof were practically the same temperature, proving clearly that air in bulk is a poor non-conductor on account of the convection currents set up. This proves that it is most necessary for air spaces to be microscopic in order that they may still contain air.

Amongst the steam engines used at collieries the most important are the winding engines. The load factor in such an engine is very low, being in the neighbourhood of 7 to 15 per cent., depending on the load, speed of wind, and depth of shaft. Mr. W. C. Mountain has shown that electric winders are less economical than steam winders, but they are nevertheless being increasingly adopted in Germany, South Africa, and elsewhere. It occurs to the writer in this connection that this is a point which is open to question, it not being sufficient to merely calculate the horse-power-hours given out by the winder for a given consumption of steam, since this is admittedly an extravagant steam user, but rather to calculate the extent to which winding electrically will lower the load-factor on the generating plant. Electrical

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winders, although absorbing a very large amount of power to produce the necessary starting torque, impose very short peaks on the generating plant.

Hauling engines are a class of engine which, unless very liberally installed at the outset, are usually working up to their full capacity, if they are not overloaded. If the engine is drawing coal up an incline, it is loaded up to nearly the last tub it can haul. With an endless-rope system of haulage the conditions are somewhat more favourable, and in some cases expansion gear is fitted, but even in such cases the result is but moderately economical. Small air-driven haulages underground are always most extravagant users of compressed air, which is, in its turn, under the most favourable conditions, as low in efficiency as 25 per cent. The overall efficiency of such plant must be exceedingly low when one takes into consideration the long ranges of pipes feeding them and the poor class of joints generally used. The writer has in mind a case of a compressed-air system where, although no leakage could be heard throughout the entire pipeline, yet absorbed 1,000 cub. ft. of free air per minute at 60lbs. pressure to maintain the pressure at this figure.

Prime movers for the generation of power take various forms, from the horizontal slow-speed engines, belted to generators, to the modern high-speed direct-coupled type. Belt- or rope-driven sets are not recommended on account of their low efficiency, inability to take high-peak loads, cost of upkeep, and space occupied. Radiation losses are considerably higher for unit power as compared with the high-speed sets, on account of the larger heated surface which must be exposed to the atmosphere owing to the lower speed. Vertical high-speed reciprocating sets have in the last few years reached a high state of efficiency and reliability, and there is little doubt that they form the most efficient steam-driven prime mover up to about 300 kw. The makers have designed these engines that reversal of the stresses is so gradual that forced lubrication is sufficient to keep the bearing surfaces from coming into contact. For powers above 500 kw. there is no question but that turbines are the most suitable. At almost every colliery there are a large number of small steam engines, all probably uneconomical in view of their small size and the condensation in the steam pipes leading from the boilers. There is sometimes a big drop in the setam pressure with these small units, and oftener a high back pressure.

Taking all these circumstances into consideration, is it not inevitable that the cost of producing power in collieries by the use of steam alone must be exceedingly wasteful, and would be much more economically dealt with by electric motors? It is interesting to try to analyse how the fuel consumed is used, and the writer has taken out the figures in the case of Wharncliffe Silkstone Collieries, the plant of which was reported on two years ago by the National Boiler Insurance Company. The coal consumed over a period of 18 days was 839 tons, which it was calculated produced $(839 \times 2{,}240 \times 11{,}840) = 22{,}251$ millions of British thermal units under the conditions existing at that time. Of these heat units produced it is calculated that 1·7 per cent. were utilised in the performance of useful work, the balance being lost in boiler losses, radiation, latent heat, inefficient engines, and the general conditions of operation. The demand for power was very unfavourable to an economical result. The winding and hauling engines worked intermittently, especially the former. Table II. gives the percentage of total heat units absorbed by the various engines :—

TABLE II.

Power used for	Approximate H.P.		Hours per day in use.	Constant or intermittent.	Percentage of total units.
	Average.	Maximum.			
Winding	100	900	16	Intermittent	14·2
Hauling	265	550	16	..	17·6
Air-compressing	200	350	24	Variable speed	17·6
Fan	235		24	Constant	26·2
Other engines	100	400	12	Various	25·66*

* The high consumption of the various engines is due to their small size and condensation resulting from long pipe connections.

Scope for Condensation and Compounding, including Turbines.—Wherever a plentiful supply of good water is available, considerable economy may be effected from condensation. It is, indeed, essential where steam turbines are used, and where the water supply is limited recourse must be had to water coolers. Surface condensers are preferred where the condensate is required for boiler feeding if the cooling water is of a readily scaling or corrosive nature. The majority of jet condensers are so arranged that the removal of scale is more easily performed than with surface condensers, as there is but a fraction of the area to be scaled. It is present-day practice to effect condensation in a condenser of the rotary type with which on the accumulation of an undue quantity of water in the impeller greater centrifugal force results, due to the higher specific gravity of the mixture in the impeller. With this arrangement, provided the speed of the impeller remains practically constant, no flooding back is to be feared.

The various types of steam turbines differ as to the manner of expanding the steam, and the arrangement which would give the best efficiency has had to be more or less modified to produce a practical machine. Present-day practice is practically the result of a compromise between such factors as steam economy, strength, cost of construction, size, weight, factor of safety, leakage losses, and steam temperature. Up to the present impulse turbines have met with great success on account of their simple form, which is not liable to distortion with the pressure and temperature necessary for their efficiency. It would appear, however, that the reaction turbines should give better results provided it were possible to use steam of the same temperature as the impulse turbines. Theoretically, the reaction turbine is the best, but the impulse turbine has the advantage over the reaction type that it has no guide blades to cause friction, and it occupies less space.

The Utilisation of Electricity as a Means of Power Distribution.—The advantages of generating power on a large scale have long been appreciated, and in this direction it has been demonstrated that central stations are generally able to provide power at a very low figure. This advantage must, however, be, to a certain extent, discounted by reason of the transmission losses which occur to a greater or less extent, depending upon the flux density, distance, and power factor. In large central power stations feeding a large area the transmission losses are naturally greater than if the same area were fed by a number of smaller stations, and in view of the waste-heat or coke-oven gas available at collieries it is evident that much economy might be effected by linking up a number of power stations and collieries. Taking, for instance, the district round Sheffield, Barnsley, and Wakefield—if all the collieries in this area were linked up to the central power station, fuller use might be made of each generating plant, and by reason of the larger amount of power pooled, high peak loads would have less effect on the system. There would not be the same necessity for spare plant, as in the event of a stoppage power could be drawn from the mains and a surplus of power is returned to the power company's mains and finds a market. The cost per unit for inflowing and outflowing current could be adjusted so as to preserve equilibrium at any desired point. With a possible 100 per cent. demand the maximum load on a generating plant is not more than 45 per cent. If this latter is true for a maximum demand of 100,000 h.p., how much more would it apply when a greater power were involved?

Gas Engines.—As a means of generating power the gas engine is about equal in point of cost with the most modern type of steam generator—including modern turbines. The comparison between reciprocating steam engines such as are found at collieries, and the low efficiency which has already been referred to, shows an immense waste of fuel and heat value. At the Carville works of the Newcastle and District Electric Supply Company current is generated at a cost of 0·132d. per unit produced, and the coal cost to produce a unit is only 0·11d. That is, the coal cost per horse-power-hour is considerably under 0·1d.

Where collieries have by-product coke ovens, the surplus gas evolved in the coking process furnishes a source of power which if not utilised is wasted. With a good class of bituminous coal and regenerator ovens 50 per cent. or more of the gas in the coal is surplus, so far as the heat required for the coking process is concerned. At Wharncliffe Silkstone Collieries with 35 non-generator and 15 regenerator ovens (Simon-Carves system) 1,300 h.p. are being obtained daily and utilised in gas engines. If the whole 50 ovens had been regenerator ovens, 2,000 h.p. would be easily available from the same quantity of coal. The calorific

value of the gas is about 430 B.T.U., and although difficulties owing to the richness of the gas were at first experienced with the gas engines, they have now been overcome, and no trouble has been experienced from this cause for some time past. The power is used both for generating electricity and compressing air, as well as for driving a ventilating fan.

Electricity	800—1,000 H.P.
Compressed air	280— 300 ,,
Ventilating fan	220— 220 ,,
	1,300—1,520 ,,

If this power had to be generated from steam on the load-factor and conditions prevailing, the lowest consumption which could be expected is some 2½lbs. of coal per horse-power-hour, which, with coal at 6s. per ton, would cost £3,400 per annum. The actual saving was probably more than three times that amount, as a great quantity of obsolete plant was thereby stopped, the steam consumption of which was much higher than that corresponding with 2½lbs. of coal per horse-power-hour.

Much has been written to prove that gas engines are thoroughly reliable machines, but such is somewhat cold comfort for one who has a troublesome case to handle, and it occurs to the writer that a few troubles from his own experience, and the remedies applied, may be useful. Cylinders and piston rods are always lubricated by fresh oil, and not more than is sufficient for the purpose should be used. Excess oil will form carbon with the attending risk of pre-ignition. Bearings are sometimes fed by drop-feed lubricators; but, except for the smaller sizes of engine, this system is not to be recommended on account of the high oil consumption. The method to be preferred with large engines is forced feed, so arranged as to supply sufficient oil to flood the bearings, the drainage falling into the bedplate, whence it is drawn through filters, pumped through the oil cooler, and returned to circulation. The oil consumption with this system is as low as 3 gallons per 24 hours for 1,000 h.p., and renders local heating almost impossible.

Pre-ignition may occur from several causes: (1) Incorrect mixture may be so proportioned as to burn in a manner more or less active (depending on the proportion of gas to air) for a considerable time. In the case of a 4-cycle engine, if the mixture is such that combustion continues during the expansion and exhaust strokes, the fresh charge drawn into the cylinder (which on the same load is identical in composition) meets the incandescent contents of the cylinder, and, in its turn, burns throughout the inlet stroke. This burning or combustion becomes far more intense on the compression stroke, and forms what the writer, for the want of a better name, terms "false pre-ignition." This cannot really be called "pre-ignition," since the cylinder has contained flame for practically the whole cycle. It is but rarely that this trouble is encountered except with gas of a high hydrogen content, such as coke-oven or town gas. Dilution of the charge with a sufficient quantity of inert gas is sufficient to overcome this trouble.

(2) With a multi-cylinder engine overload may occur, due to the refusal of some of the cylinders to take up their proper load. This may be due to a throttling of the charge or misfiring. The importance of reliable ignition cannot be overestimated. It is, in fact, so important that most makers fit ignition plugs in duplicate, and some Thyssen engines seen by the writer at Zollverein Colliery, at Caternberg, were fitted with ignition in triplicate.

(3) Incandescent matter in the combustion chamber generally takes the form of carbonised oil, tar, and such dust as is drawn from the atmosphere with the inlet air. The presence of sulphur in the gas will cause such dirt as accumulates to bind together and adhere to the cylinder walls. Asbestos joints, if allowed to project beyond the jointing faces into the cylinder, are apt to become incandescent, and are sufficient to cause pre-ignition. Overheated ignition plugs are a common source of trouble, and in this connection the writer has experienced much difficulty with an 8-cylinder vertical tandem gas engine. This trouble has, it is hoped, been permanently cured by the adoption of Lodge ignition plugs, which are mica insulated.

(4) The regularity and reliability of the ignition is dependent on the magneto. In the case of a high-tension magneto, with its distributor, a very small amount of carbon, dust, or dirt is sufficient to short-circuit adjacent terminals, which would, of course, cause ignition to occur at an incorrect time. It is imperative that magnetos should be reliable and inflexibly connected to the timing shaft, as the slightest alteration of the setting of the magneto renders breakdown imminent.

STRUCTURAL ALLOY STEELS.*

BY HENRY D. HIBBARD.

STRUCTURAL steels have some attributes in common, which makes it worth while to consider them collectively to a certain extent. These steels are working great improvements in the production of structures for various purposes, especially where the saving of weight or increase of strength or both are important, the most conspicuous example being undoubtedly the automobile industry. Heat-treated alloy steels with double or treble the strength of the simple steels they replace and with as great or greater reliability are now in regular and most advantageous use. In common with other alloy steels, structural alloy steels owe a part of their superior properties to the presence of the alloying element, but usually far more to heat treatment when it can be given to them. In automobiles the use of alloy steels is generally not advised unless the steels are heat treated, as the gain from their use in the natural or untreated state does not compensate for the increased cost.

Most structural alloy steels are therefore used in the heat-treated condition, when the articles made of them are, like automobile parts, not too bulky or massive. Large pieces like nickel-steel rails and nickel-steel members of bridges are used without heat treatment, the advantages of increased strength and ductility that the metal possesses being due solely to the presence of the alloying element.

The difficulties attending the heat treatment of large steel parts that are bulky for their weight are holding back their general introduction. They require, as nearly as is practicable, to be uniformly heated, uniformly cooled in quenching, and afterward, when cold, to be made true to form, as the quenching operation, however carefully done, usually leaves them warped or twisted. No doubt, in time, means will be found to overcome these drawbacks, and such pieces as rails and bridge members of alloy steels will be used regularly in the heat-treated condition. A compact object like an armour plate, though very large, may be quenched without unmanageable warping because of its simple shape. The difficulty in making straight and true such an article as a heat-treated rail of pearlitic alloy steels lies largely in the springiness of the treated metal. It is not easy to give it the correct amount of set needed to counteract or obliterate a crook, bend, or twist that may result from quenching. Yet this is necessary when the piece must be straight or true to shape. Stretching slightly beyond the elastic limit as is done to some thin steel sheets and relatively small bars to straighten them might be efficacious, but is not to be easily done with a piece of such irregular cross-section as a rail

The effects of heat treatment are so great that a certain steel may be given a very wide range of properties, depending on the treatment, and any desired set of properties within that range may be obtained solely by varying the heat treatment. The principal variant is the degree of the second heating. The lower this is, the stronger and stiffer the steel, and the higher, the weaker and more ductile it is. This effect of heat treatment on steel is illustrated by a table published by a producer giving the results of 40 tensile tests made from one heat of steel, each test piece having had a different heat treatment. Five, which cover the range, are given in the table below:—

Tensility. Pounds.	Elastic limit. Pounds.	Elastic ratio. Per cent.	Elongation in 2in. Per cent.	Contraction of area. Per cent.
84,850	50,500	60	28	67·5
120,975	90,000	74·5	14·5	51
166,950	157,500	94	12·5	44
205,600	200,000	97	13	48·7
240,975	225,000	93	9	20·5

Analysis of the original steel showed C, 0·25; Mn, 0·50; Cr, 1·07; and V, 0·17 per cent., but similar results could be obtained with a variety of compositions.

For making small parts that must be true and well finished

* From a bulletin on "Manufacture and Uses of Alloy Steels," issued by the United States Bureau of Mines.

the structural alloy steels are generally heat treated before they are machined, and this requirement prevents the use in such parts of steel of the highest strength attainable because steel having that strength is not commercially machinable. Generally speaking, any part that is to have an elastic limit of more than 100,000lbs. per square inch must be treated after having been machined, not before, because most steels having a higher elastic limit than that are too hard to allow machining by commercial processes, though chromium-vanadium steels with an elastic limit of 150,000lbs. per square inch are claimed to be machinable, that is, they may be cut with high-speed steels at a profitable rate. An elastic limit of 100,000lbs. or more per square inch can be imparted to steel only by heat treatment, as no untreated steel of a commercial grade will have so high a limit.

Some of the makers of structural alloy steels are publishing for each of their steels a graph showing the physical properties the steel will have when hardened and then drawn to different temperatures. Of course, the graphs give ex parte information which is subject to confirmation before acceptance, but the plan is excellent as giving the most information in the least space. Similar graphs of many alloy steels prepared by consumers are expected to be soon available for comparison. From these graphs a new user of these steels may choose the properties he desires and specify the steel he wishes, making some allowance of course (say 10 per cent.) for the uncertainties of manufacture and treatment. The steel maker or treater, to be reasonably sure of meeting the requirements, will aim to exceed the properties specified, and the net result will usually be that the steel will have practically the properties desired.

The size or massiveness of the article has a great effect on the results obtained by any given heat treatment. The greater the mass the lower the qualities, though not in exact proportion. Thus the mass must always be considered in connection with the properties desired, and the composition and heat treatment prescribed must be modified accordingly, though even then the effect of mass may be only partly compensated for. The modulus of elasticity of many, if not all, structural alloy steels, in common with other steels, is not changed much by heat treatment or variations in composition and is usually between 28,000,000lbs. and 30,000,000lbs. per square inch; that is, the modulus of the steel in its annealed, hardened, and tempered condition remains practically unchanged. The following table was compiled from data given by Landau.

Composition of Steel

C. Per cent.	Si. Per cent.	Mn. Per cent.	P. Per cent.	S. Per cent.	Cr. Per cent.	Ni. Per cent.	V. Per cent.	Modulus.
0·50	0·13	0·82	0·01	0·02	1·25	—	0·14	29,240,000
0·47	1·83	0·70	0·01	0·01	—	—		28,950,000
0·48	0·16	0·44	0·01	0·01	0·98	2·02	—	28,840,000
0·30	0·19	0·64	0·01	0·01	—	3·25	0·18	28,260,000
0·25	0·21	0·74	0·01	0·01	—	3·55	—	28,170,000
0·24	0·21	0·46	0·01	0·02	0·96	2·02	—	28,200,000
0·25	0·16	0·50	0·01	—	1·05	—	0·16	30,158,000

Because of the unchangeability of the modulus of elasticity the stiffness or rigidity of steel within the elastic limit is not changed either by heat treatment or the presence of any of the alloying elements, except perhaps manganese in manganese steel and nickel in high-nickel steels. Heat treatment does increase the elasticity, however, so that a piece of heat-treated steel may return to its original form after having endured a stress that would have permanently deformed it in its untreated condition; that is, it is given some of the springiness of heat-treated springs. Many of the structural steels, particularly those used in automobile manufacture, have a great endurance against fatigue when subjected to repeated alternating stresses. The heat treatment increases their durability in this test even more noticeably than it does the properties determined by the tensile test.

Personal.—The Executive Committee of the City and Guilds of London Institute have appointed Mr. W. Eccles, D.Sc., A.R.C.S., M.I.E.E., to the Professorship of Electrical Engineering and Applied Physics at the Institute's Technical College, Finsbury, rendered vacant by the recent death of the late Prof. Silvanus P. Thompson, F.R.S.

THE MYSTERY OF THE SCREW PROPELLER.*

BY CAPTAIN C. W. DYSON, U.S.N.

For many years after the adoption of the screw propeller for the propulsion of ships, the seeming vagaries in its performances on actual service cast a mystery over it and over the laws governing its action. The greater part of this mystery is, however, not due to the propeller, but can be directly attributed to the carelessness with which trials of ships have been run and data collected; and the larger part of the remainder to the effect of variations in full form in interfering with the proper flow of water to the propeller, thus seriously decreasing the propulsive efficiency; the effect of wake in increasing propulsive efficiency; and the incorrect estimation of effective horse-power through neglect in allowing for the malign influence of the appendages, such as struts, bilge keels, &c. The small remaining portion of the mystery can be ascribed to the propeller itself, and is due to the myriad variations in blade form and section which have been used, and to the lack of a consistent basis of comparison for an analysis of propeller performances. As the years rolled by they brought in their wake the model tank, by which a more nearly accurate value of the effective horse-power can be obtained; more accurate instruments for the measurement of indicated and shaft horse-powers; better mechanical construction of propelling engines; more care in running trials over the measured mile, combined with a better knowledge of the effect of shallow water. These improvements have resulted in the production of data from which curves may be drawn, rendering it possible to estimate a curve of performance for any vessel with more than a fair degree of accuracy.

When a propeller works at the stern of a vessel it operates in a body of water which partakes, to a greater or less degree, of the forward movement of the vessel itself. When the propeller is so situated that the suction column of water entering the propeller disc enters normal to the disc and with very little disturbance, and when the propeller blade tips are well immersed and pass the hull at a good distance from it, the wake will increase the effective thrust of the propeller, and therefore the effective horse-power delivered, for any given indicated or shaft horse-power. This gain is known as wake gain.

Should the propeller be so situated in relation to the hull that the suction column is no longer a cylinder, but becomes a frustrum of a cone, the propeller disc being the upper bounding plane, or should the propeller blades be insufficiently immersed or pass unduly close to the hull, or should combinations of the above conditions exist, the effective thrust, and consequently the effective horse-power for any indicated or shaft horse-power, will be reduced. This is commonly called the thrust deduction. In cases where the thrust deduction exceeds the wake gain—and such cases are those that usually exist—the result is a net loss in propulsive efficiency and an increase in revolutions for a given speed. Where the wake gain exceeds the thrust deduction, the opposite effects are produced.

All screw propellers when working under similar conditions of resistance arrange themselves in one great family, in which the position of any particular propeller was fixed by its diameter, pitch, and projected area ratio, the latter fixing the dimensions of the thrust and the resultant tip speed and propulsive efficiency which may be expected. As the condition of the resistance changes, the values of the thrusts and tip speeds change in inverse proportion. These thrusts, tip speeds, and propulsive efficiencies can be shown graphically as curves, the abscissæ values of which are projected area ratios, and the family position of any propeller can be found by using these values to ascertain the indicated or shaft horse-power and the effective horse-power which the propeller will deliver under the conditions of resistance which produce such curves. Curves of the kind are given in the author's work on "Screw Propellers," but experience has shown that higher values

* From the "Journal of the American Society of Naval Engineers."

of propulsive coefficient can be realised above 0·56 projected area ratio than were credited in the original curve.

At one time the author advanced the statement that the point of cavitation depended upon tip speed and effective thrust. He now considers that this statement is in error, and that the words "tip speed" should be eliminated, for the tip speed at cavitation will vary with the effective horse power being delivered, while for equal effective thrusts this effective horse-power will vary inversely as the speed of the ship, and a change in effective horse-power carries with it a change in revolutions. Should a propeller working in the wake of a certain hull cavitate at a certain speed while delivering a certain effective horse-power, it will, should the loading of the ship be changed, cavitate at any new speed where the effective thrust delivered is the same as that being produced under the original conditions of loading.

In comparing estimates for vessels with their actual performances, the difference between model tank conditions of hull smoothness and water conditions, and those that actually exist under trial conditions of the real ship, must be appreciated. It is hardly possible to obtain an exact similarity of these conditions, and therefore the actual effective horse-power for the model and ship may differ considerably, and a difference between the estimate and the actual performance will thus be produced. The principal causes of such differences of condition are roughness of ship's bottom, adverse conditions of wind and sea, undue shallowness of water on trial course, poor helmsmanship, and possible error in assuming that the law of comparison holds for hull appendages. On this latter point, however, the estimates made where trial conditions were good in all respects agree so closely with the actual performances that it appears to be practically certain that the law of comparison does apply to the hull appendages.

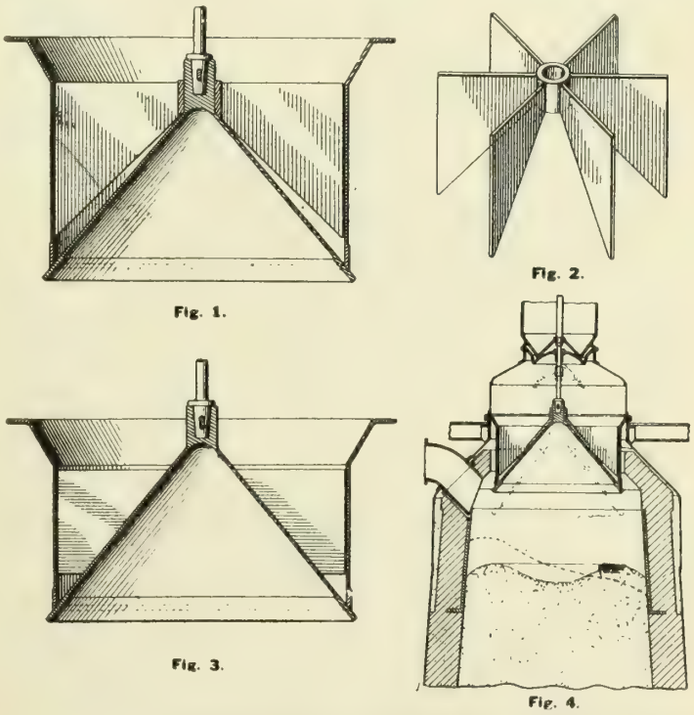
It has often been noted in the cases of large vessels driven by turbines and by reciprocating engines that when the resistance for any given speed is increased to any extent, the propellers of the reciprocating-engined vessel immediately demonstrate a great superiority over those of the turbine-engined one, and this is still further accentuated when the sea conditions impose an additional load on the effective horse-power.

Naval Constructor Taylor, U.S.N., has demonstrated that with vessels of ordinary battle-ship form a decrease in resistance of about $1\frac{3}{4}$ per cent. occurs when the ship is trimmed approximately 3ft. by the stern. This percentage decrease does not constitute the only gain that occurs in such cases, for by so trimming the vessel there is a considerable increase in wake, with a corresponding wake gain for the propeller, so that the thrust deduction remaining constant there results a large gain in propulsive efficiency, made up of the two factors, decreased resistance and wake gain.

The conclusions arrived at from an examination of many ships' results are: (1) That the efficiency of a propeller is seriously affected by its position in relation to the hull of the vessel; (2) that for any given propeller working under constant hull conditions of form, the effective horse-power for any given engine power remains constant, and this is independent of the speed of the vessel; (3) that for any given propeller working under constant hull conditions of form, the revolutions necessary to deliver any given effective horse-power vary with the speed of ship, the engine power remaining constant; (4) that model tank effective horse-power curves are correct, and that appendage resistance varies according to the laws of comparison; (5) that trials of vessels over shallow water courses should be prohibited, as such courses change completely the character of water-flow to the propeller; (6) that deep-water trials, by the close agreement of actual with estimated results, demonstrate the correctness of above statements; (7) that torsion meters and indicators give accurate results on official trials, and that the large estimate of from 3 to 5 per cent. error usually credited to these instruments is incorrect, particularly at high powers; (8) that results obtained from model tank experiments with model propellers will be correct when the model is properly proportioned to the full-sized propeller; (9) that where vessels are entered into competition based upon relative efficiencies of their propelling machinery, it is a positive error to base these efficiencies upon speed or revolutions, as both speed and revolutions per minute for equal load, represented by equal effective horse powers, vary with the loading of the hull, foulness of the ship's bottom, weather, and sea, while it shows that the criterion for efficiency of propelling machinery should be indicated or shaft horse power developed, and that the speed of the ship and revolutions of the propeller should be neglected.

NEW CHARGING BELL FOR BLASTFURNACES.

We are indebted to the "Iron Trade Review" for the following particulars of a charging device for blastfurnaces, recently patented by Mr. Julian Kennedy, engineer, Pittsburg. The device is designed to guide and control the charge in such a way as to promote better distribution in the furnace. Some of the difficulties experienced in securing uniform distribution arise from wet stock, which will not slide as readily as dry material, from corrosion of portions of the top of the bell, the corroded parts offering greater resistance to passage of the stock, or from a lateral movement of the bell which throws the stock to one side, where it remains. The details of Mr. Kennedy's invention are clearly shown in the accompanying illustrations. Fig. 3 is a vertical section through one form of the bell, and through the feed hopper of a blastfurnace. A modified form of the bell is shown in Fig. 1. Fig. 2 is a perspective view of the guides shown in Fig. 1. Fig. 4 is a vertical section through the top of a blastfurnace, another form of guides being connected to the bell. The



Charging Bell for Blastfurnaces.

guides or wings shown in Fig. 2 are claimed to ensure protection from the difficulties mentioned. The guides which are shown in Figs. 1 and 2 are cast integral with the central hub. They can be rotated about the boss of the bell, thus shifting the wings so that unequal wear of the top of the bell is prevented. The stock passes between these wings, thus being guided as it falls into the furnace. The guides are also designed to retain the bell centrally within the hopper. In the design shown in Fig. 1, the wings do not contact with the upper surface of the bell, so that portions of the stock commingle between the bell and the lower portion of the guides. In the design shown in Fig. 3 the wings do not extend to the outer edge of the bell, permitting the stock to commingle before falling into the furnace. Fig. 4 also shows the distribution which, according to Mr. Kennedy, results from the use of the device. The dotted line shows the irregular level of the materials in the furnace, which frequently occurs with present practice.

THERMO-ELECTRIC PROPERTIES OF FUSED METALS.

SOME experiments on the thermo-electric properties of fused metals were shown by Mr. Chas. R. Darling, A.R.C.S., Lecturer in Physics, Finsbury Technical College, at a meeting of the Physical Society of London, on June 30th. The experiments shown related to observations made during the progress of a research, having for its object the production of a thermo-electric pyrometer with a liquid element. If such a pyrometer could be made of suitable materials—such as graphite and molten copper—it might be possible to extend the useful range of base-metal pyrometers up to or beyond the melting point of platinum, as the boiling point of copper is 2,310° C. In seeking a satisfactory couple, experiments were first made with molten tin in the following manner: An iron crucible was inserted in a hole in a sheet of uralite, so that its rim was flush with the upper surface of the sheet. A groove was made in the uralite, commencing at the crucible, and the molten metal was then poured into the crucible until it overflowed, and then along the groove, at the end of which a cold junction was formed with the second metal. A wire dipping into the crucible formed the hot junction; and by this arrangement a continuous circuit was maintained between the liquid in the crucible and the solid in the groove. Advantage was taken of this arrangement to observe the effect of fusion on the electromotive force developed, about which little information appears to exist. It was noted that when tin was partnered by iron, nickel, copper, constantan, or graphite, no abrupt change occurred at fusion, the electromotive force temperature curves showing no break. Using iron and tin in this manner forms an instructive lecture experiment. Starting from the cold, the electromotive force rises steadily; remains constant during fusion at 232°, and then rises to a maximum at 340°, after which inversion takes place—the whole change occupying only two or three minutes, when a small crucible is used. On substituting lead, zinc, and bismuth in turn for tin, and using a variety of wires, it was again found that the change of state caused no alteration in thermo-electric properties. In the case of bismuth, however, three instances of thermo-electric "halt" were noticed, the electromotive force attaining a maximum and then remaining unchanged over a considerable range of temperature. An iron-bismuth couple reaches a maximum of about 18 millivolts at about 250° C. (M. Pt. of Bi = 269), which remains constant to within 3 per cent. up to 550°, beyond which it has not been investigated. Copper and bismuth behave in the same manner, the electromotive force being practically the same as in the former case; whilst aluminium and bismuth furnish a third example, the electromotive force (about 15 millivolts) being remarkably constant over a range of 300°. A previous instance of this kind was observed by Barrett with a couple of pure iron and an Fe-Ni-Mn alloy. A suggested form of liquid-element pyrometer was described, and it was suggested that the experimental methods shown might prove useful in the thermal investigation of alloys, as the formation of definite compounds would probably be accompanied by a notable change in electromotive force. The steady electromotive force furnished by the Bi-Al couple might also be used in work in which a constant, low electromotive force was required.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Reversing and regulating gear for internal combustion engines. Kilburn. 216.
Charging receptacles with gases under pressure. Vickers, Ltd., and Smith. 564.
Steam condensers. Ramsay. 5223.
Machines for manufacturing twist drills. Wilt. 5367.
Concentration of ores. Howard, and Minerals Separation, Ltd. 5454.
Kerosene vaporisers for internal combustion engines. Scully, Smith, & Barker. 9784.
Automatic press for metal stamping. Péranne. 9859.
Means for actuating the fuel pumps of internal combustion engines. Ogle. 9876.
Reducing attachment for automatic multi-spindle lathes. Blackburn. 9885.
Torsion power indicator apparatus. Chadburn & Woodward. 9888.
Combined lighting and ignition systems for use with internal-combustion engines. Neuland. 9908.
Water tube boilers. Turnbull. 10056.
Apparatus for casting steel ingots. Kennedy. 10101.
Pipe joints. Hatt. 10156.
Shaft packings. British Thomson Houston Company. 10242.
Internal combustion engines. Tacchi, and Centrum Syndicate, Ltd. 10247.
Valve gear for pneumatic tools. Christiansen. 10331.
Turbines. Brockelbank. 10379.
Valves and cocks. Derham. 10802.
Carburetters for internal-combustion engines. Daimler-Motoren-Ges. 10820.
Feed water filters. Watson & Billetop. 10940.
Water purifier, oil remover, and circulator for steam generators. Pomeroy's "Moa" Water Softener Syndicate, Ltd., and Pomeroy. 11588.
Fastenings for wire ropes. Head, Wrightson, & Co., Wrightson, and Ringquist. 12670.
Manufacture of hollow castings. Humber, Ltd., and Buchanan. 13282.
Speed-reducing gearing. Dey. 13735.
Controlling the supply of oil fuel to oil engines. Crossley and Hutton. 13882.
Motor pistons. Rich. 15069.
Method of polishing and preserving iron or steel from rust. Van der Meulen. 16979.
Furnaces for heating billets for tool forgings. Price. 17574.
Feed water heaters for steam generators. Daneri. 17928.
Apparatus for cutting screw threads in lathes. Lambourne, and John Warrick & Co. 18163.

1916.

Fluid pressure braking apparatus. Westinghouse Brake Company. 588.
Ball bearings. Schatz, J. W. 3465 and 3466.
Air compressors. Reavell & Co., and Reavell, W. 4025.
Fluid pressure gauges. Bradley, E., and Richards, G. B. 5011.
Valves and valve-gear of internal combustion engines. Serex, C. E. 5774.
Ball grinding machines. Deutsche Waffen-und Munitionsfabriken 5852.
Axial flow turbines. Reede, A. A. W. van. 6125.
Treatment of feed water for steam generators. Laraque. H. 6613.
Automatic turret lathes. Wilt, A. D. 7097.
Valve mechanism. Miller, H. P. E., and Tetlow, E. 8106.

ELECTRICAL, 1915.

Electric time switches. Horstmann, and Horstmann Gear Company. 10067.
Incandescent electric lamps. Casotti. 10121.
Electrical switch controlling devices. House. 10938.
Contact breakers of induction coils. Codd. 14382.

METAL QUOTATIONS.

TUESDAY, AUGUST 1ST.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled	1/3⅝ per lb.
,, tubes (brazed)	1/4¾ ,,
,, ,, (solid drawn)	1/2¾ ,,
,, ,, wire	1/2⅞ ,,
Copper, Standard	£111/–/– per ton.
Iron, Cleveland	82/6 ,,
,, Scotch	— ,,
Lead, English	£29/–/– ,,
,, Foreign (soft)	£28/–/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
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Silver	30$\frac{9}{16}$d. per oz.
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Railway and Shipping Freights.

AMONGST the various handicaps to British exporters that have grown up under our *laissez-faire* trade policy none have been more severe or call more loudly for consideration at the present moment, when the trade facilities after the war is so prominently occupying the attention of the authorities, than that resulting from the special freight rates which his German competitor has enjoyed both for internal and overseas traffic. In Germany the extent which railways are state-owned no doubt permits of this encouragement being more easily accorded than here, where the railways are entirely private-owned companies, which, whether working in opposition or in unison seek, naturally, to serve their own interests rather than those of the trader. True, as public carriers their powers are subject to legislative control, and the granting of special export rates is to some extent regularised, but this is only partial as compared with German practice, where goods marked for export are carried on the railways at approximately half the ordinary rates charged for inland traffic, and in some cases are as low as one-third of one penny per ton per mile. How this compares with rates here is shown by the fact that these rates are lower than our charges for bulked goods like coals and minerals. Where special export rates are granted to our traders it is usually on account of shipping competition or because of a large export trade from some particular manufacturing centre, not out of any studied desire on the part of carrying companies to promote export or traders' interests. It is true these interests may be regarded as selfish individually, but in the aggregate they are national and there can be no question of the need for supporting them in the inevitable trade struggle after the war. The anomalies of freight classification at present are many, and the fact that these have arisen in many cases as a result of development in particular in-

dustries only goes to show the need that exists for a more flexible controlling authority in intimate touch with trade requirements when viewed from a national standpoint. At present heavy machinery, which includes all kinds of engines, steam, gas, and oil, may be rated under what is termed "mileage" scale instead of the arbitrary point to point rates charged for other machinery. Now electrical machinery does not come under "mileage" classification, and hence in shipping a turbo-alternator, while the turbine may be charged at the mileage rate the alternator is charged at the machinery rate. There is of course no valid reason for this differentiation, and the anomalies arising out of it become the more pronounced when it is borne in mind that the machinery rate is not a fixed one for all classes of machinery, but is subject to percentage additions on account of weight, which introduces further arbitrary distinctions. It is of course easy to understand that strict uniformity is not applicable, and that the carrier's task may be complicated by the nature and mass of the load. But that only emphasizes the need for an elasticity which shall be regulated by common sense and a just appreciation of the needs of the trader as well as the rights of the carrier, and at present this is often conspicuous by its absence. An example will serve to illustrate this. Suppose, say, a manufacturer wishes to dispatch an alternator of which the motor weighs, say, 23 tons. If the ordinary machinery rate is 20s., the special rate for this weight would be 30s., or with a rebate for cartage, say, 27s. per ton. For an equivalent weight the rate on the mileage scale would be about half this. Hence we have this anomaly, that while any form of steam, gas, or oil engine weighing 23 tons could be carried 80 miles for a little over £14, an alternator or part of one of the same weight would be charged over £28, and this, it may be added, is not an extreme case. For heavier pieces or longer distances the handicap on electrical machinery would be even greater. That a thorough overhaul of railway and shipping freights is needed in justice to British traders is as clear as that the operation of through rates has in the past greatly handicapped him in competition with his German rival. The injustice is one to which the British Electrical and Allied Manufacturers' Association is, we are glad to say, fully alive and are taking active steps to remedy, and we hope in this effort they will be efficiently backed by public opinion. The days of indifference and individual interests are gone and must give way to collective action for collective welfare.

TRADE AFTER THE WAR.

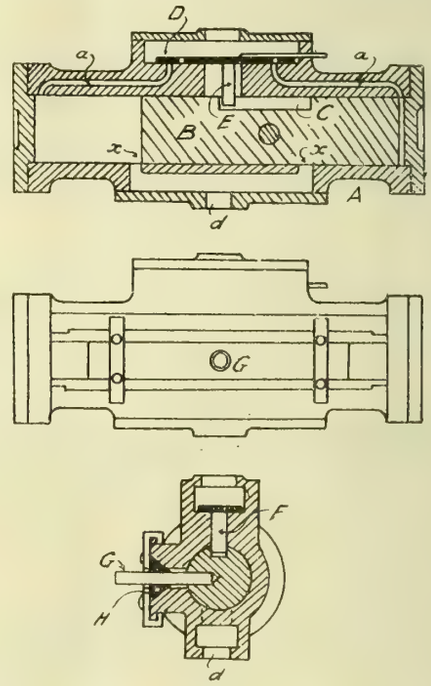
THE following announcement has been issued by the Press Bureau:—

The Prime Minister has appointed a committee to consider the commercial and industrial policy to be adopted after the war, with special reference to the conclusions reached at the Economic Conference of the Allies, and to the following questions: (*a*) What industries are essential to the future safety of the nation, and what steps should be taken to maintain or establish them. (*b*) What steps should be taken to recover home and foreign trade lost during the war, and to secure new markets. (*c*) To what extent and by what means the resources of the Empire should and can be developed. (*d*) To what extent and by what means the sources of supply within the Empire can be prevented from falling under foreign control.

The committee is composed as follows: The Right Hon. Lord Balfour of Burleigh, K.T., G.C.M.G. (chairman), Mr. Arthur Balfour, Mr. H. Gosling, Mr. W. A. S. Hewins, M.P., Mr. A. H. Illingworth, M.P., Sir J. P. Maclay, Bart., the Right Hon. Sir A. Mond, Bart., M.P., Mr. Arthur Pease, Mr. R. E. Prothero, M.P., Sir Frederick H. Smith, Bart., Mr. G. J. Wardle, M.P., together with the following gentlemen who are presiding over Board of Trade committees on the position of important industries after the war: Sir H. Birchenough, K.C.M.G., Lord Faringdon, Sir C. G. Hyde, the Hon. Sir C. A. Parsons, K.C.B., F.R.S., Lord Rhondda, Mr. G. Scoby-Smith. Mr. Percy Ashley, of the Board of Trade, and Mr. G. C. Upcott, of the Treasury, have been appointed secretaries to the committee.

ORIGIN OF THE UNIFLOW ENGINE.

IN a contribution appearing in the July issue of the "Journal of the American Society of Mechanical Engineers" Mr. Wm. E. Bullock states that it is generally conceded that the uniflow principle was invented in England by L. J. Todd, who took out his patent for this invention in 1886. Apparently Todd's invention was never put into practice, but on December 10th, 1895, the two brothers Cleveland took out an American patent for a uniflow cylinder, which was first put on a traction engine and later on locomotive No. 59 of the Canadian Intercolonial Railway. Some time since the writer had occasion to look into the history of the uniflow engine, and found an early American patent showing, although not claiming, the uniflow principle. The date of this patent was November 12th, 1867, and the patent was granted John M. Hirlinger for an improvement in steam engines (U.S. patent No. 70,841). Hirlinger's invention is shown in the accompanying cut. It consists of a steam cylinder A, with both ends permanently closed. Upon one side is formed a V-shaped channel, in which works a similarly-shaped slide H. G is a bolt which passes through H, and



VIEW OF CYLINDER WORKING ON UNIFLOW PRINCIPLE INVENTED IN 1867.

has its inner end secured fast in the piston B. The steam chest has within it a cut-off valve D, which has on its under side a pin E, extending into the cylinder into the recess C in the piston. The valve D has two steam openings communicating with the steam ways *a a*, which admit steam to the cylinder. The playing of the piston in the cylinder causes the valve to move so as to admit steam at each end. This arrangement of valve with its pin and the piston with its recess dispenses with the necessity of having cams and rods for working the valve. The steam, when exhausted, escapes through the openings *x x* and *d* at the under side of the cylinder. As stated above, the inventor did not claim the embodiment of the uniflow principle, from which we must assume that the idea of exhausting the steam from a cylinder through ports at or near the centre of its length, and of controlling the opening of the exhaust ports by the ends of the piston, was not patentable (had already been utilised) in 1867, or was not regarded as of sufficient merit to warrant protection by a patent.

Engineering Standards Committee.—At a special meeting of the Main Committee (Sir John Wolfe Barry, K.C.B., chairman) held on July 27th last, Mr. Charles le Maistre, A.M.Inst.C.E., M.Inst.E.E., who has been in charge of the work of the Electrical Section since 1903, was appointed secretary to the committee, in succession to the late Leslie S. Robertson, M.Inst.C.E., who was lost with Lord Kitchener in the disaster to H.M.S. "Hampshire."

COAL RESOURCES OF THE UNITED KINGDOM.*

BY ARNOLD LUPTON, F.G.S.

At the outset I propose to establish the truth of the following statements: (1) That the coal resources of the United Kingdom are sufficient for its domestic requirements and foreign export, and that there is no occasion for legislators to trouble themselves as to our future resources of fuel. (2) That the coal resources of the rest of the world, though vast in proportion to those of the British Isles, are not larger in regard to the area of land which now or in the near future they have to supply, and that therefore the exhaustion of the coalfields of the rest of the world will proceed at much the same rate as those of the United Kingdom. (3) That there are other sources of power and heat sufficient to take the place of coal in the United Kingdom and other parts of the world, although they cannot, at the present time, except in certain localities and for certain purposes, compete with cheap coal. (4) That during the cheap coal period an abundant supply of metals will be mined and smelted, so that with prudent care they will be sufficient for the use of later generations with comparatively small renewals by further mining and smelting.

My attention was first directed to the question of the duration of our coal supplies by speeches made by the then Sir William Armstrong and Mr. Hussey Vivian, M.P. Armstrong said that our reserves of coal were being rapidly exhausted; Hussey Vivian replied that they were ample. In 1866 the Government appointed the Royal Coal Commission to enquire into the amount of our reserves of coal and their probable duration, and in 1871 the Commission delivered the report, which was replete with information of the greatest value. In 1901 the second Royal Coal Commission was appointed, which reported in 1905; this report also contained a great deal of information. The eminent geologist, Prof. Hull, wrote a book dealing with our coal resources, and the late Prof. Stanley Jevons made a most valuable contribution on the economic aspects of the question. He developed the remarkable and startling proposition: That the more economy was practised in the use of coal, the more would its consumption increase, because economy in its use made that use more profitable. The experience of the 40 or 50 years following the issue of that book had amply demonstrated the truth of that proposition. In considering the effect of increase of population upon the increased consumption of coal, the first Royal Commission consulted the eminent engineer, Mr. Richard Price Williams, M.Inst.C.E., who drew a curve showing the probable increase of consumption at a diminishing ratio. The subsequently ascertained facts had proved the substantial accuracy of Richard Price Williams' prediction.

The Royal Commission reporting in 1871 gave the total amount of coal, the existence of which it considered to be absolutely proved in seams 1ft. and more in thickness at a depth not exceeding 4,000ft., as 97,528,000,000 tons. In addition, the geologists considered to be probable at a depth of less than 4,000ft. a quantity of 56,246,000,000 tons, making a total of 153,774,000,000 tons. The commission which reported in 1905 gave the total which it considered to be absolutely proved in seams of 1ft. and more in thickness above the depth of 4,000ft. as 100,914,000,000, and below that depth an additional quantity of 5,239,000,000 tons; and the Geological Committee reported a further quantity at depths less than 4,000ft. of 39,483,000,000, making a total of 145,636,000,000. Between the two reports upwards of 5,695,000,000 tons of coal had been got. If this is added to the 145,636,000,000 above given we get a total of 151,331,000,000 tons, which is about 1½ per cent. less than the estimate of the earlier commission. It is, however, unfortunate that in both the commissions the summary totals given in the general reports are not so much statements of facts as statements of opinion, because the figures above quoted are not the actual tonnages of coal supposed to be in the earth, but the actual tonnages which the commissioners believed might some day be raised to the surface, and how they arrived at the figures which are given cannot be gathered with exact precision from the reports.

In the 1871 report Mr. Hussey Vivian, reporting on the western part of the coalfield of South Wales, deducted one-third for faults, pillars, barriers, and small coal left behind. Mr. Clarke deducted the same proportion from the eastern part of the South Wales coalfield. Mr. Woodhouse, in giving the report for Yorkshire, Derbyshire, Nottinghamshire, Leicestershire, and Warwickshire, deducted 44 per cent.

In the report of 1905 deductions varying from 18 to 26 per cent. are made on account of barriers and pillars for the support of buildings and loss in working due to faults and other natural causes, but nothing is said in the general report about deductions for waste in working, and no details are given for the Yorkshire, Derbyshire, and Nottinghamshire districts as to the deductions. In the case of South Wales, however, the deductions are given by the late Lord Merthyr (then Sir Wm. Thomas Lewis), and apparently amount to about 21 per cent. In Scotland, according to the report of Mr. G. S. Dixon, 26 per cent. has been deducted. For Northumberland, Durham, and Cumberland, Sir Lindsay Wood has made deductions varying from 20 to 30 per cent. For Yorkshire, Nottinghamshire, and Derbyshire, Mr. A. Currer Briggs makes deductions varying from 33 to 58 per cent. What deductions the geologists have made in the 1905 report is not clear. It appears to be pretty certain that on the average the commissioners have taken not less than 40 per cent. off the estimate of coal available.

The waste of coal which may have been necessary when the average price of coal free on board ship was 10s. a ton may be quite unnecessary when the average price is 20s. a ton, and most improbable when the average price is 40s. a ton; and yet we have to bear in mind the fact that the time will come when the average price of coal at the pit top will be £2 or £3 a ton. With coal at these high prices, under ordinary conditions of trade and labour it would pay to pick up by hand every pound of coal in the mine and carefully to sift the dirt from the slack. When coal is cheap, a fault may render it impossible to reach a small area of coal; when coal is dear, small faults will be no hindrance to the workings. When coal is dear, barriers of coal will no longer be left between adjoining properties unless to keep back water, and even as regards those, the time may come when barriers of cement concrete will be substituted for coal, as being cheaper. Therefore, when coal becomes expensive it is not likely that there will be any waste of coal at all, and not 1 per cent. of it will be left in the ground.

As regards the small coal that is now left in working and the inferior portions of thick seams and unnecessary barriers, this is now called "waste in working," but it is not really waste from the point of view of national resources in the future. The small and otherwise inferior coal which is now left in the pit is really stored up there for future use, and the day will come when miners will work over the old coal workings for slack and inferior coal, and it will all be brought out and utilised.

The Royal Commissions, in deciding to take no account of seams below 1ft. in thickness, were guided by the experience of the past, but in considering the future, the past of cheap coal is no guide as to what will be done in the future with coal at £3 a ton. Coal has already been worked in seams as thin as 1ft. where it happens to have some specially excellent quality or a high-priced local market; but with coal at 40s. a ton on the pit bank, a seam 3in. in thickness might be got, and at 60s. a ton it might be possible to work a seam only 2in. in thickness. Therefore, in forecasting the future and in considering what our mineral resources will be 500 to 1,000 years hence, we must take into consideration all the coal there is.

Since the Royal Commissions reported the Kent coalfield has been extensively proved, and there is every reason to believe that other considerable coalfields are likely to be proved in hitherto unexplored parts of England where possible coal measures are covered with newer formations. Coal workings have already reached a depth of 4,000ft. in some places, and if the price of coal were high enough, coal might be got from a depth of 10,000ft. The temperature of the earth at that depth would be perhaps 212° Fah., but with a strong ventilating current the miners could be kept cool whilst working. The experience gained at present depths seems to show that, as

* Paper read before the South Wales Institute of Engineers, July 27th, 1916.

the depth and pressure increase, the rocks also will acquire a sufficient strength to resist the pressure, so that coal may be got in the ordinary way.

The report of the commission in 1871 is in some respects more convenient for correction than that of 1905. Therefore, the figures of that report are taken as a basis, and instead of allowing 40 per cent. or more for waste in working, only 4 per cent. is admitted, raising the available percentage from 60 to 96 per cent., that is to say, by 60 per cent. An examination of many sections of coal indicates that not less than 10 per cent. may be added to the total tonnage of thicker coals, for coals under 1ft. thick. For the coalfield of South-east Kent and other possible coalfields in the South of England not yet proved, 16,000,000,000 tons is added. For possible extensions of the Yorkshire and Nottinghamshire coalfield beyond the limit made in 1871, 10,000,000,000 is added.

It will be interesting to refer to the great coalfield of South Wales. According to the 1905 commission the total tonnage of coal at that time in reserve was about 35,700,000,000 tons. Adding 10 per cent. for coal under 1ft. thick, we get 3,570,000,000 tons, or a total of 39,270,000,000 tons. Revising the deductions in that report and substituting a total deduction for losses of all kinds of 3,000,000,000 tons, we have left 36,270,000,000 tons. Deducting coal got from December, 1903, to December, 1915, about 580,000,000 tons, the total of Welsh coal in reserve is shown to be 35,690,000,000 tons. With an output of, say, 60,000,000 tons a year, this would last 595 years. But the maximum output, whatever it is, 60,000,000 or 120,000,000 tons a year, will not be maintained to the end, but will gradually decline. Men will be working coal in South Wales 5,000 years hence.

There is a strong probability that coal will be found in the concealed coalfields at a greater depth than 4,000ft., and as there is no reason for limiting the estimate to that depth, an addition is made for these deeper coals. Therefore the 1871 figures for deep coal are adopted. With these corrections, the tonnage available in 1871 appears as in the following table:—

	Millions of tons.
Exposed coalfield	90,207
,, ,, over 4,000ft. deep	7,320
Covered coalfield proved and probable	56,182
,, ,, ,, 4,000 to 6,000ft. deep	25,840
,, ,, ,, 6,000 to 10,000ft. deep	15,302
Total	194,852
Add 60 per cent. for reduced waste in working	116,911
Add 10 per cent. for coals under 1ft. thick	31,176
Add for coalfield of South-east Kent and other possible South of England coalfields	16,000
Add for possible extensions of Yorkshire and Nottinghamshire coalfield beyond the 1871 limit	10,000
Total	368,939
Deduct coal got since 1871 report	8,817
Coal remaining to get in 1916 ... about	360,000

In the United Kingdom the amount of coal raised in 1913, the last pre-war year, was 287,000,000 tons, as compared with 230,000,000 in 1903, and 188,000,000 in 1894 (1893 was a strike year), 160,000,000 in 1884, and 126,000,000 in 1874.

	Tonnages.	Increases in Ten years.
1874	126,000,000	—
1884	160,000,000	34,000,000
1894	188,000,000	28,000,000
1903	230,000,000	42,000,000
1913	287,000,000	57,000,000

Having regard to the character of the new collieries recently established and about to be established in parts of Great Britain, there is every reason to suppose that the next decade will show a great increase in coal production; that is to say, it would show this great increase if we assume that the war will make no difference. It is, therefore, highly probable that the annual tonnage raised in this country will continue to increase until it has reached the figure of 350,000,000 or even 400,000,000 tons a year.

For the purpose of argument, it is necessary to put a limit to the increase of production, and putting that at between 350,000,000 and 400,000,000 tons a year, at that rate our coal would be exhausted in 800 to 1,000 years from the present date. This period is but short in the history of the world, but it is long having regard to the history of the civilisation of this country, and the future is filled with so many possibilities that it would be presumptuous to make oneself anxious because of changes in our material resources at that distant date. Our coal, however, will never be worked out entirely. Its price has been steadily increasing for some years and, quite apart from the abnormal conditions of a war, the price is likely to continue to increase and also the cost of getting, and when we come to work very thin seams at very great depths, the cost per ton will be three times what it is now. As the cost of coal increases the use of substitutes for coal will increase so that the time will come when these substitutes will be very largely used and coal will be reserved for special purposes and special occasions, so that it will never really be exhausted.

The following table gives in roughly approximate figures the area in square miles of the various divisions of the world, the population of each division, and the possible area occupied by coalfields in each division. The amount of coal in the five divisions of the world is taken from "The Coal Resources of the World," published by Morang & Co., Ltd., Toronto, Canada, in 1913. The amount in the United Kingdom and the populations are the author's own estimates:—

Actual, Probable, and Possible Reserves of Coal.

	In million tons.	Populations.
Oceania	170,410	10,000,000
Asia	1,279,586	800,000,000
Africa	57,839	200,000,000
America	5,105,528	150,000,000
Europe	784,190	390,000,000
	7,397,553	1,550,000,000
United Kingdom	360,000	48,000,000

Reserve of Coal per Head of Population.

United Kingdom	7,500 tons.
Europe	2,000 ,,
The whole world	4,772 ,,

The total annual output of coal in the whole world before the war was probably about 1,200 million tons. From the above table some rough idea may be obtained of the relations of the United Kingdom with the other parts of the world. As regards many parts, their coalfields are yet substantially intact. This applies to China and some other parts of Asia, South America, Australasia, and Africa, whereas our coalfields have been worked for hundreds of years, and during the last hundred years with great vigour. But notwithstanding that, the United Kingdom has to-day 97 per cent. of its original reserves still intact.

The annual production of the United States is already about double ours; China is vigorously engaged in the construction of railways and other mechanical works, so is Australasia, so that as regards the exhaustion of coalfields the various countries of the world start in the twentieth century upon much the same basis, and if in the United Kingdom coal is exhausted sooner than elsewhere, it will be because the rapid increase and vigour of our population has enabled us to make better use of our property. And if we convert a due proportion of our coal into permanent works enabling us to utilise other sources of energy, we need have no fear for the future.

Practically almost all the coal in the United Kingdom is of first-class quality. Here and there is a seam with an undue proportion of sulphur or of dirt, but that is quite the exception. The variation in quality in the coals worked to-day which makes all the difference in the market price, considered chemically or in its capacity for the production of heat, is very slight; so that taking a wide view of the question, we may say that all our coals are of first-rate quality, and having regard to the future, the chief difference between one seam of coal and another will be in its thickness, inclination, and hardness, questions affecting cost of getting more than its usefulness when got.

In considering our competition with China, it is not likely that the change from a 4ft. seam to a 2ft. seam will very materially affect the relations of the competition, and at a still later date it is not likely that the change from a 2ft. seam to a 1ft. seam will, at that time, materially affect the relations of the competition.

If all the coal raised was used to produce power, then the world's coal production of 1,200,000,000 tons a year, if consumed in 300 days, each 24 hours long, and assuming that 1½lbs. will give 1 b.h.p. for one hour, or say 2,000 b.h.p. for one ton for one hour, it would give 330,000,000 b.h.p.; or if we assume that all the coal was consumed each day in 10 hours, it would give 800,000,000 b.h.p.

We may calculate the coal production in the near future as equal to 1,000,000 tons for every day in the year except Sundays and holidays, or in round figures, and taking a day as being 24 hours long, 40,000 tons an hour. If we consider that 1 ton will produce 2,000 h.p. in the very best engine for one hour, calculating that 1⅛lbs. of fuel per hour will give 1 b.h.p., that gives us a total power of 80,000,000 h.p. day and night all the year round (except Sundays), if all the coal we raised was used for the production of power, or if all consumed in 10 hours would give 192,000,000 b.h.p. Of course, the coal will not all be used in the form of engine power, but in a great variety of processes of which engine power is only one. In an exceedingly interesting and instructive address by Dr. Dugald Clerk, F.R.S., he has stated the total horse-power produced by coal in the world at the present time as follows: World's factories, 60,000,000 h.p.; world's railways, 19,000,000 h.p.; world's ships, 23,000,000 h.p.; total, 102,000,000 h.p.

There is no doubt that economies in the use of coal will continue to be devised and adopted in a great variety of ways. For instance, in warming and cooking in our houses two-thirds of the present fuel consumption might be saved. Probably half the fuel consumed in factory engines can be saved, and it is likely that in the course of 100 years from now we shall, on the average, get from coal three times the average useful effect we get from it now, so that the population of this island might be more than doubled without it being necessary to consume more coal than we consume at present.

In talking of the coal question, it is common to hear people say that we must consider natural gas and petroleum, but there is no evidence to suppose that these useful fuels will outlast the coal reserves of the world, and indeed, that except as production from shales, it is not likely that they will last so long.

The total amount of water power in the world has been estimated by A. H. Gibson (Professor of Engineering in the University of St. Andrews) at "well over 200,000,000 h.p., or more than enough to provide mechanical energy for the whole present work of the world," an estimate not at all excessive. Eminent engineers have estimated the available water power in Scotland at 1,000,000 h.p., and it is probable that the remainder of the United Kingdom could furnish, if necessary, another 1,000,000 h.p.

As regards driving factories by the wind, the chief difficulties are the irregularity of the wind and the first cost of the windmill, and therefore it is only when coal gets to a high price that the windmill will be largely used for heavy work. In considering this question, many writers have assumed that the windmills of the future will be similar to the ordinary windmill one sees nowadays, but that is not at all probable.

For a long time it has been known that the sun's heat might be utilised to produce steam. Sun steam engines have now been made on a practical scale, and one of 50 h.p. has been erected in Egypt at Meadi near the River Nile, not far from Cairo, for the purpose of pumping water for irrigation. There are enormous areas of sunburnt desert in Asia, Africa, America, and Australia where the mighty power of the sun is in evidence almost every day, where sufficient condensing water could be obtained at a moderate expense over many millions of square miles. But if the sun power is in the Sahara Desert, what use is that to the people of the United Kingdom? The answer is that this power can be transmitted electrically at a very moderate cost, as may be shown by the following calculation:—

It is assumed that a current of 2,000 kw. can be passed through an iron cable, 1 sq. in. in section, at a tension of 100,000 volts, so that 10,000,000 kw. would require a section of 5,000 sq. in. This would weigh 50,000lbs. a yard, or rather less than 10,000 tons a mile. Fifteen hundred miles would weigh 60,000,000 tons, and this at £10 a ton would cost £600,000,000. The cost of tunnels and wayleaves and other works might be £200,000,000, making a total first cost of £800,000,000 (the cost to us of 160 days of the present war). When once this cable was established, the cost of repairs would be trifling, and assuming that the interest on money at that period is as formerly, from 3 to 4 per cent., the total annual cost of the cable might be put down at 5 per cent., or £40,000,000 a year. This on 10,000,000 kw. is £4 per kilowatt. Working nine hours a day, we have 3,285 hours a year. The cost is, therefore, 0·29d. per kilowatt-hour. The boiler as now designed costs about £30 per brake horse-power. Taking repairs and attendance at 10 per cent., the annual cost is £3. The engine and electric generators might be made for £6, and taking the annual cost at 10 per cent. equals 12s. per brake horse-power. Total cost of boiler and engine, £3. 12s. per brake horse-power per annum. Allowing 25 per cent. for loss in generation and transmission brings the cost up to £4. 10s. Adding the cost of the transmission line, £4 and 10s. for sundries, brings the total annual cost up to £9 per kilowatt. For nine hours a day, or 3,285 hours a year, this equals 0·654d. per hour. To this, of course, has to be added the cost of transformation and distribution. But the total cost would be quite comparable with present charges in this country for electrical energy.

The author has made some very rough calculations tending to show that in some places in this country tide power might be profitably used when the price of coal had reached £4 a ton, and when that time comes the tide power in many other parts of the world will be extensively used for the transformation of energy for industrial purposes.

It is a question of some interest as to how far the continued combustion of mineral fuels will so alter the quality of the atmosphere we breathe as to lower the vitality of the human race as at present constituted; if this change in the atmosphere is likely to take place, it is highly improbable that in the short space of time in which it will occur, say 1,000 years, the human body will have had time to adapt itself, but the following calculation seems to show that we shall probably still be able to breathe when all the fossil fuels in the world have been burnt up.

One pound of carbon requires 2·67lbs. of oxygen or 12lbs. of air for complete combustion. The weight of air on every square inch of the surface of the globe is rather more than 14lbs. The total weight of coal, adding to it oil, mineral gas, and peat, is, say, 8,000,000,000,000 tons, and assuming that eight-tenths of the total weight is carbon, that gives us a weight of 6,400,000,000,000 tons of carbon requiring 12 times that weight of air for complete combustion. The superficial area of the globe is about 453,000,000 square miles; then the ratio of the weight of air burnt when all the mineral carbon is consumed to the total weight of the atmosphere is shown by the following calculation, which the writer thinks is approximately accurate:—

$$\frac{\overset{\text{Square miles.}}{453{,}000{,}000} \times \overset{\text{Acres.}}{640} \times \overset{\text{Sq. yds.}}{4{,}840} \times \overset{\text{Sq. ft.}}{9} \times \overset{\text{Sq. in.}}{144} \times \overset{\text{lbs.}}{14}}{\underset{\text{Tons.}}{6{,}400{,}000{,}000{,}000} \times \underset{\text{lbs.}}{2{,}240} \times 12} = \frac{148}{1}$$

that is to say, the total atmosphere is 148 times the amount required for combustion, and the burnt air will be 0·68 per cent. of the total, the weight of carbonic acid gas about 0·3 of the total weight of coal and burnt air, or $0{\cdot}68 + \frac{1}{12} =$ say $0{\cdot}74 \times 0{\cdot}3 = 0{\cdot}222$ per cent. of the total atmosphere. The Mines Regulation Act allows 1·25 per cent., or six times as much. There is, therefore, nothing to fear from the carbonic acid gas in the air so long as the present meteorological conditions prevail, and there is plenty of wind to keep mixing the air up and moving it about the world.

Every consumer of coal has the strongest reason for trying to reduce his coal bill, and every owner of a coal mine has every reason for economising his resources, and these reasons

have operated so strongly that within the lifetime of living people the most wonderful economies have been effected; without the aid of any legislation and without the guidance of any Government official, the consumption of coal in a steam engine has been reduced from about 10lbs. per brake horse-power to 1½lbs. Gas engines have been largely introduced which require 1lb. of fuel per brake horse-power, or even less. In the manufacture of iron and steel similar economies have been introduced, and by means of electric central power stations great economies have been rendered possible. Nothing can hinder or stop the efforts of the practical people to make further economies of fuel unless it is Government interference.

Some people are very anxious that the Government should teach us how to work our coal mines economically. They suggest that the deepest seams should be worked first; they suggest that if a coal seam is divided into two parts, one good and the other bad, when the good part can be sent out at a profit and the bad part can only be got at a loss, that both good and bad should be got instead of permitting the present process of leaving the bad part in the mine. They would make it compulsory to send all the slack coal out of the mine and forbid the leaving of any pillars or barriers. All this they would do in the name of economy. They forget that economy is a very complicated matter.

If, for the sake of argument, by Government interference the cost of getting coal was increased by 1s. a ton, that means the use of additional labour and additional material in the shape of wood, iron, oil, &c. Now that additional labour and material may involve an expenditure of coal and other valuable things much greater than the value of coal which is supposed to be saved.

Those people who wish to insist that parts of a seam of coal which are left in the mine because it does not pay to get them out should be got out, forget that the coal which is left in the mine is not wasted; it is stored up. The real waste would consist in bringing it out of the mine when it isn't wanted. When the time comes that it is wanted, it will then be economical to get it. When coal is worth £2 a ton at the pit bank, all sorts of that mineral which is now regarded as rubbish will then have great value. There is nothing new in the idea of working a coal mine over again. In South Staffordshire mines have been worked and closed, re-opened, and worked three times over.

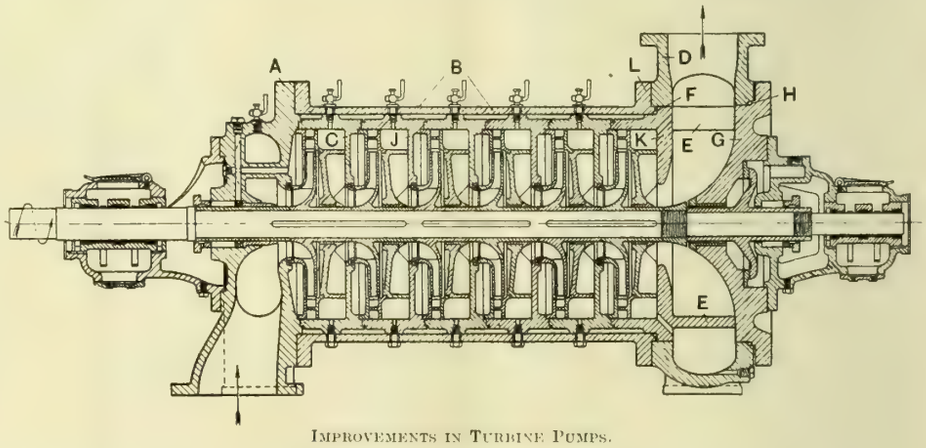
United States Output of Bauxite and Aluminium in 1915.—Bauxite and aluminium output in the United States in 1915 reached record proportions according to the U.S. Geological Survey. The production of bauxite was 297,041 gross tons, valued at $1,514,834, an increase of 35 per cent. weight and of 41 per cent. in value over the 1914 output. This very large increase was due to increased activity in the aluminium industry and the greatly lessened amount of foreign bauxite imported. Of a total consumption of more than 300,000 tons, little more than 1 per cent. was imported. Metallic aluminium consumed in the United States in 1915 was 99,806,000lbs., and there was still a great scarcity, according to W. C. Phalen, of the Survey. This was due to a greatly increased demand and a curtailment of imports. Aluminium powder has been extensively used in making ammonal, a high explosive, by mixing it with ammonium nitrate.

Presses and Dies.—From John Hands & Sons, Ltd., Birmingham, we have received an excellent catalogue, &c., of hand and power presses for all kinds of stamped work, with specimens of work now done in this important branch of engineering. Incidentally, also, the catalogue gives some useful information respecting the technical phrases employed in connection with tools of this kind, which is valuable to those considering the question of use or purchase.

IMPROVEMENTS IN TURBINE PUMPS.

HITHERTO it has been usual to build centrifugal pumps of the turbine type, that is to say, pumps containing several impellers and diffusers with solid cylindrical casing, or similar casings split in the horizontal centre plane, alternatively the pumps have been made with casings divided at right angles to the axes, the number of units generally corresponding with the number of stages, and therefore called stage casings, and held together by bolts or studs passing from end to end. The design with one cylindrical casing for all stages either solid or in halves has the drawback that special patterns are necessary for any required number of stages, and that dismantling may be troublesome owing to internal parts sticking to the casing due to rust. The drawback of the pump built in stages without an outer casing, as above described, is the impossibility of dismantling the pumps without breaking either the suction or delivery pipe joint.

In order to obviate the drawbacks of both constructions, Messrs. Rufener & Wiesengrund, Horton Bridge, Yiewsley, Middlesex, propose in a recent patent to assemble the stage casings, which have water-tight joints between each other, in a plain outer cylindrical casing which can be moulded with striking board and is not subject to any water pressure, but merely serves the purpose to hold together the separate suction and delivery end of the pumps besides centring the stage casings. The delivery end is made with such internal diameter that all the stage casings can be withdrawn without fouling the delivery end. The delivery end is an annular chamber with a circular cover, which contains the automatic balancing



IMPROVEMENTS IN TURBINE PUMPS.

device, varies the delivery end bearing, and when bolted to the annular delivery chamber holds the various stage casings firmly together. In order to take the pump to pieces it is only necessary to take off the delivery end cover, when all internal parts of the pump can be withdrawn without breaking any pipe connection.

Referring to the illustration, A is the suction end of the pump bolted to the cylindrical outer casing B. C, J, &c., are the stage casings contained in outer casing B. The first stage casing is fitted to the suction end A with water-tight joints, and similar joints are formed between the stage casings, the number of the latter varying according to requirements. The last stage casing marked K is provided with a flange and projections E. A small clearance space is allowed between the flange of the last stage casing and the flange of the outer casing. Into this clearance space a packing ring F, of suitable material, is inserted. Centred on the flange L of the outer casing and bolted to the latter is the annular delivery chamber D. Bolted to the delivery chamber is the end cover G. A clearance space is provided between the flange of the end cover and the delivery chamber, the water-tight joint being made by a suitable packing ring H. When the end cover G is bolted to the delivery chamber its inside presses against the projections E, and thus establishes the tight fit of the water-tight joints of the stage casings. It will be seen that with this construction the stage casings, with the parts which they contain, can be withdrawn after removal of the end cover G, whilst suction end A and delivery chamber D remain in position bolted to outer casing B, so that the pipes which join on to A and D respectively can remain undisturbed.

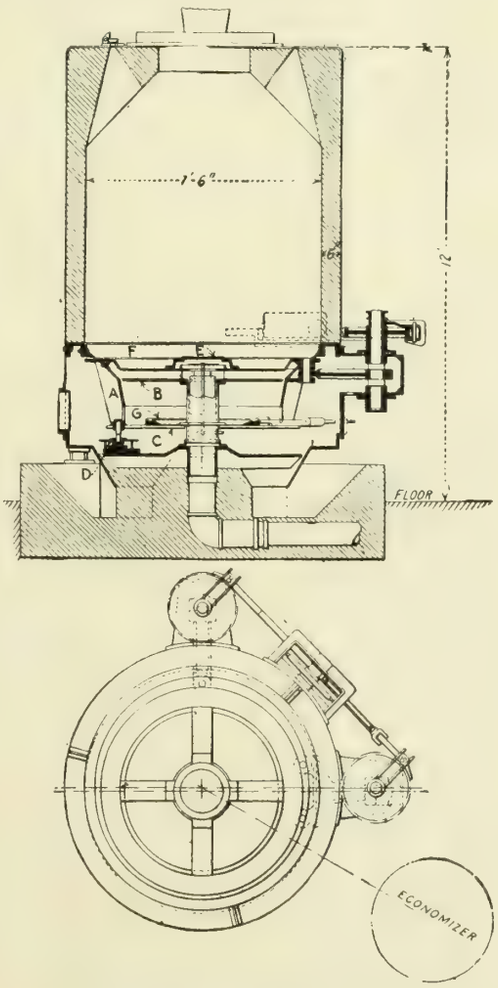
NEW MECHANICAL GAS PRODUCER.

We are indebted to our American contemporary "Power" for the accompanying illustration and following particulars of a mechanical gas producer which has recently been perfected by the Flinn & Dreffein Company, Chicago. In the new producer the entire fuel column, the centre as well as the sides, is agitated to cause the fire to settle. The ash line is maintained at a point about a foot above the bosh, and above this a fuel bed about 2ft. thick is maintained. From the sectional and plan views of the generator, the construction will be evident. The entire bosh A, tuyere B, and ash table C rest on four sliding supports, the sliding surfaces D being tightly housed to keep out the ash and packed with high-temperature grease. By a driving mechanism the various members just mentioned are given an eccentric motion, in which every part has the same travel, unlike plain rotation in which the motion is zero at the centre and a maximum at the circumference. The bosh and tuyere arms, having a firm hold on the ash and moving in an eccentric path, are resisted by the stationary brick walls of the generator. This causes the entire column of ash and coal to rise and fall slightly along the walls with each rotation, thus settling the fire and breaking down any arching effect of the ashes which would eventually produce holes in the fuel bed. The ash-discharge ring G is held fast by four extensions passing through the shell of the generator. If the fire tends to settle more on one side, then the ring is moved toward the opposite side by loosening up on one nut, holding one of the extensions through the shell and taking up on the opposite side. As the bosh and ash table move and the ash ring is stationary, the relative motion results in the crushing of any clinkers formed and in pushing the ashes off the table. The ashes fall loosely into the water seal below, from which they can be removed in the regular way. Motion is imparted to the grate by two eccentric drives mounted 90° apart on the outside of the generator shell. On the vertical shafts carrying these eccentrics are ratchet wheels. Midway between these drives is a bracket carrying a horizontal shaft upon which is a sprocket-wheel chain connected to the source of power. On this same shaft is an eccentric which gives a reciprocating motion to a crossbar, at each end of which is a pawl for engaging the ratchet wheels imparting motion to the grate.

About four years ago the American Can Company, of Maywood, Ill., installed three gas producers of the ordinary hand-poked type, two being 7ft. 6in. and one 6ft. 6in. diam., the rated capacities being 300lbs. and 200lbs. of coal per hour, respectively. Anthracite at a rate of about 10lbs. per hour per square foot of cross-sectional area of the generator was used to supply gas to the can-making machinery, to lacquer, japanning and varnish-baking ovens, and to a number of hardening furnaces. The recent addition of a lithographing plant and increasing demand in the can works required considerably more gas. The layout of the producer room would not permit installing another generator without remodelling some of the manufacturing plant. The alternative was to install mechanically-operated grates in the present producers. The two larger generators were equipped with the new Flinn & Dreffein grates. These producers with their new grates have been in operation for a number of months. Working continuously and for long periods, they have gasified 18lbs. to 21lbs. of coal per hour per square foot of sectional area, and on peak loads for short runs the rate has been as high as 24lbs. per hour, which may be compared to the 10lbs. per square foot originally obtained.

A better and more uniform gas is being generated, and the ashes are free from carbon. Formerly the ashes had to be sifted for unburned coal. Now it is not necessary to stop operation for cleaning fires; instead, the mechanical grate is operated for a period of $1\frac{1}{2}$ hours twice during the working day, or, in other words, every six hours. At the cleaning periods the operator takes readings of the height of ashes above the bosh. This is done by inserting a light bar into the fire until the end rests on the top of the bosh and measuring up to the part of the bar showing colour. Records at the plant show that about 15 per cent. less coal for the same output is used than when the hand-poked producers were operated, and about 10 per cent. more gas is produced per pound of coal. Coal is supplied to the generator by a half-ton electric travelling hoist with a detachable bucket. On the first floor this is placed on a carriage and conveyed to and back from the coal storage. The bucket is then elevated to the charging platform and the coal fed to the generator as it is needed.

From the generators the gas passes through economisers to a common main. It then enters a coke and excelsior scrubber, 6ft. 6in. diam. and 25ft. high, serving the entire plant. From the top of the scrubber the gas is drawn by either one of two exhausters, each directly connected to a vertical engine. The exhauster delivers the gas to the supply main under a pressure of $1\frac{3}{4}$lbs., the speed of the engine being automatically controlled by the gas pressure through a diaphragm valve. The gas delivered is indicated and recorded by a venturi meter. Air for combustion is drawn through the economiser by a steam blower mounted on the side of the generator. The mixture of steam and air is forced under pressure through the centre pipe of the generator and out into the ash at the centre tuyere cap E, or out through the tuyere arms



Sectional and Plan Views of Gas Producer.

B under the annular tuyere ring F. By actuating a lever, a drum and disc in the centre pipe may be raised or lowered, causing the moist air to flow at the centre or at the outside, as desired. The amount of steam and consequently the quantity of air supplied to the generator is automatically controlled by a gasometer connecting with the top of the generator. Here a pressure slightly less than atmospheric is maintained. Any variation in pressure up or down influences the position of the gasometer, and in turn increases or lessens the opening of the steam valve.

It is thus evident that the operation of the plant throughout is practically automatic. The air and steam supply to the generator is automatically controlled, as is the pressure and supply of gas to the supply main. The fire level and the discharge of ashes and clinker into the water seal is cared for by the mechanism connected to the grate. It is estimated

that the driving mechanism on each generator requires about ½ h.p. The quality of the gas runs about 150 B.T.U. per cubic foot. While it is used for industrial purposes in the present plant, the gas can be generated with equal advantages for power purposes. The mechanical feature may be applied to old producers, saving the installation of additional generator capacity.

RECRYSTALLISATION OF BOILER TUBES.*

BY A. E. WHITE AND H. F. WOOD.

AT a central steam boiler plant in Detroit where very heavy loads were carried for a number of weeks at a time, the metallographic examination of tubes showing incipient failure revealed coarse crystals at the surface of the tube exposed to the high temperature. These failures also universally occurred in the front row of tubes where the temperature was highest and only on the side exposed to the flame. The question then naturally arose as to the conditions under which the coarse crystallisation could have resulted. The effect of time, temperature, and stress, therefore, on boiler-tube metal was accordingly investigated.

The object of the present research has been as follows: To obtain a curve indicating the relation between the time and temperature governing crystal growth at temperatures below the critical range in a deformed low-carbon steel; and to make a systematic study of the conditions existing where low-carbon steel is used at moderately high temperatures, after having been subjected to sufficient stress to result in permanent deformation, and to ascertain if the recrystallisation phenomena, known to exist under such conditions, have any influence upon the possible failure of the metal. To accomplish this, a steel of the following chemical composition was used: Carbon, 0·113 per cent.; manganese, 0·479 per cent.; phosphorus, 0·023 per cent.; sulphur, 0·035 per cent.; silicon, 0·023 per cent.

Under normal ratings, the bagging of a tube at this particular central station seldom occurs, but when high rates of evaporation are maintained over long periods of time, trouble of a more or less aggravating nature is encountered. It is felt that the difficulty is due to heavy ratings combined with thin scale deposits. The authors feel that the presence of a thin film of scale on the inside of a tube may so interfere with a rapid heat transmission that a tube may become locally overheated. The temperature to which the metal may arise will be well above that found in the tubes free from scale, and yet below the upper critical temperature of the metal. Such a temperature would in no way affect grain size in thoroughly annealed metal, but it may materially induce and produce grain growth in low-carbon steel previously deformed at temperatures below its critical point. This latter phase is the condition almost universally encountered in the boiler tubes used in present-day practice.

Under the best of refinements it is difficult to see how a tube perfectly free from strains can be obtained. Therefore, it is difficult to see how a tendency for coarse crystallisation from such metal can be prevented. It is possible to make tubes with a higher carbon content, or possibly with the same carbon content as at present, but containing a special element, such as nickel, which will not possess the same strong recrystallisation tendency. These features merit consideration, and, in fact, the first one is about to undergo a trial at one of the central heating stations in Detroit.

The extent to which coarse grains make low-carbon-steel boiler tubes weak and brittle, however, was determined by a number of tension and fatigue tests. Three sets of samples were employed; the first of untreated metal, the second of metal annealed for 10 minutes at 950° C., and then cooled in the furnace, and the third of coarse-grain metal, produced by stressing all of the test specimens the same amount and in all cases past the elastic limit, and following this by an annealing for a period of three hours at a temperature of 800° C.

The elastic limits and tensile strengths of the untreated samples averaged 34,420lbs. per square inch for the former and 54,450lbs. per square inch for the latter; while the values for the annealed samples were 21,700lbs. per square inch and 50,507lbs. per square inch, respectively. Such results showed that these samples had as good physical properties as could be expected from any metal of like composition and heat treatment. The elastic limit and the tensile strength of the coarse-grain samples averaged 14,117lbs. and 39,633lbs. per square inch, respectively. These results were 58·2 and 43·1 per cent. lower than were the results of the untreated samples, and proclaimed, therefore, a decidedly inferior grade of metal.

The actual stresses occurring in a boiler tube are tension and shear. If the principal stress resulting from a combination of the tension and shear becomes greater than the elastic limit of the metal, failure will take place. Since a coarse-grain metal has such an exceedingly low elastic limit, its use should be avoided when it is possible to get metal with a much higher elastic limit.

A very interesting development in connection with the tension tests is the fact that the percentage of elongation and the percentage of reduction of area remain practically constant throughout the entire series. This shows that the ductility of the metal is but little affected by the size of the crystals. It may therefore be said that coarse-grain ferrite is weak, but not brittle.

Fatigue tests were run on samples prepared in the same way as those for the tension tests. The coarse-grain metal was found to have an average resistance to fatigue 16·43 per cent. lower than the untreated and 77·75 per cent. lower than the annealed samples. This is very important when one considers that boiler tubes are constantly under the influence of alternating stresses.

The many conditions studied and developed have resulted in the acquisition of a number of generalisations which, it is trusted, will prove to be of some value in certain connections. The six most important ones are summarised as follows:—

(1) The time-temperature relations for every fall of temperature of 25° C., starting at 625° C., governing the recrystallisation of deformed low-carbon steel at temperatures below the Ac1 critical point, follow the formula for geometrical progression, that is:—

$$T = a,\ ar,\ ar^2,\ ar^3 \ldots\ldots\ldots\ldots ar^{n-1},$$

in which T represents time in minutes and a and r are equal to 8 and 3, respectively.

(2) The etched surface of deformed low-carbon steel does not undergo the process of recrystallisation when heated, even for long periods of time at temperatures below the critical point, although the metal immediately below the surface does show such change.

(3) The recrystallisation process on deformed low-carbon steel is an exceedingly rapid one at all temperatures below the A3 point and above 700° C., and between these limits recrystallisation takes place in all cases in a fraction of a minute.

(4) It is felt that perhaps the transformation occurring at 690° C. has some effect upon the recrystallisation process, since crystal growth took place at 700° C. in a fraction of a minute and at 675° C. in eight minutes. The present investigation has been insufficient, however, to warrant any definite statement on the matter. It certainly offers a splendid opportunity for further work.

(5) The evidence obtained during the present investigation seems to show that boiler tubes, if kept free from scale, will never fail because of the recrystallisation of the ferrite crystals. A very thin layer of scale in the tubes, however, resulting in rise in temperature of the metal, may result in the recrystallisation phenomenon.

(6) Low-carbon steel in a deformed state is so stable at atmospheric temperatures that the time temperature influence alone, at such temperatures, would probably require thousands of years for the production of crystal growth.

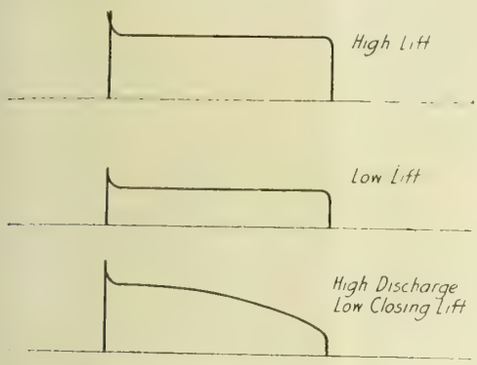
* Abstract of paper presented at the annual meeting of the American Society for Testing Materials, June 28th, 1916.

Rich Iron Ore Deposits.—According to a Valparaiso journal, of the rich iron ores, graded at over 60 per cent., the world's stock is estimated to be 2,521,000,000 tons. From this total must be eliminated 1,095,000,000 tons from Sweden (on account of the prohibition of export of pure ores) and 400,000,000 tons from Brazil (principally from the State of Minas Geraes).

STEAM SAFETY VALVES.*

BY GEORGE H. CLARK.

The object of this paper is to place on record the experimental work and conclusions drawn therefrom, of an investigation into the theory and design of a safety valve. Safety valves have been in the past and are at present the result of cut and dry methods, rather than a mechanism based on logical and fundamental principles. The theory which is here presented is believed to be general in its application, and original in character. In the course of the experimental work undertaken at least 50 valves have been built and tested, and during the course of the experimental work I have not tested, or seen in operation under test, a single valve of a design which is now



Figs. 1, 2 and 3 Diagrams of Lift Characteristics

on the market. Each valve built and tested has been for the purpose of proving or disproving a step in the theory which follows.

At a glance, it seems that the problem of the design of a safety valve should be a simple one, but when the facts are brought into line, the problem becomes increasingly difficult. All present-day valves employ huddling or expansion chambers, although those best fitted to know the reasons for their use disagree as to the actual part played by such chambers in the action of the valve in which they are incorporated. This is one example of the apparent mysteriousness relative to the action of present-day valves. It is hard for the engineering public to understand why it is not possible to increase the lift

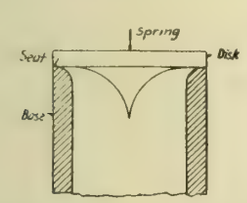


Fig. 4.—Valve Incorporating Standard Orifice Equivalent.

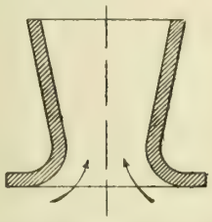


Fig. 5.—Pressure Varying Inversely as Area.

of valves in accordance with the demands of the day for high-capacity valves, without endangering the boilers to which they are connected or the valves themselves, and it is probably true that this misunderstanding is due to the lack of reasonable explanations, in which those best fitted to know concur. The pros and cons of high and low lift valves have been discussed in great detail, and I believe that I am giving the consensus of opinion in this regard in the statement that high lift valves, so-called, produce more or less shock at closure which may injure the boiler itself, and is usually a serious factor in determining the life of the valve.

A moment's consideration will show that increasing the lift is, except for changing the seat angle, the only available means of substantially increasing the relieving capacity of a valve of given diameter, and further consideration, when the tendency in steam boiler practice is taken account of, results in the conclusion that high-lift valves must come into common use. The absolute necessity for high discharge capacity valves has led English designers to employ auxiliary pistons acted on by boiler pressure, and adapted to produce high lift. To us this seems an awkward method of solving the problem, when it is remembered that most producers of safety valves state that they can build high lift valves of the ordinary type. In spite of the economical and commercial advantage to be gained, such valves are not upon the market, and are, in fact, frowned upon by both manufacturers and users.

Most specifications in force at the present day, both abroad and at home, are based either on grate area or heating surface, and are recognised by engineers to be misleading and entirely inadequate for present-day practice. This fact is evidenced by the innovations contained in the report of the Boiler Code Committee, which bases the relieving capacity on the greatest possible amount of steam that can be generated, and provides that valves shall take care of this maximum amount. There is nothing to be said in criticism of this standpoint, as experience tells us that every boiler plant will some day have to depend on its safety valves to prevent destruction, and that in this emergency they should not be found wanting. The difficulty of this method is the lack of capacity of valves of the present day to provide means for economically taking care of the situation.

The factors which tend to limit the discharge capacity of the ordinary type of valve when high lifts are attempted are the apparent impossibility of regulation and the shock produced at closure. The actual valuation of the shock produced at closure defies calculation for many reasons, but it can be shown experimentally that the height from which the disc drops to sudden closure plays an important part. The diagrams shown by Figs. 1 and 2 represent graphically the lift characteristics of high and low lift valves, a study of which shows that they are essentially alike in all characteristics, but that in high-lift valves the distance through which the disc drops to sudden closure is much greater than in the low-lift valves. If this is the case, the logical solution would seem to be a valve giving a diagram like that shown by Fig. 3 in which the lift during the blowdown period gradually decreases to a small value before sudden closure takes place. We are not vitally interested in the discharge capacities of valves during the blowdown period if high lift can be maintained at the popping pressure. If their discharge capacity is such that after blowing, the blowdown period is finally reached, the emergency is taken care of, and the installation is safe. To produce a valve that will give the diagram shown in Fig. 3, it is necessary to keep the disc in equilibrium with the boiler pressure, while that pressure is being reduced.

In any safety valve there are three factors affecting the rate of flow over the seat that are characteristics of the seat

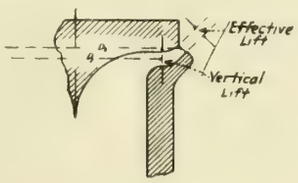


Fig. 6.—Valve with Maximum Pressure between Lips.

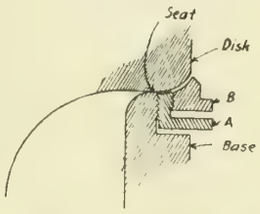


Fig. 7. Valve Adjustable for Variable Lifting Force.

itself, namely, the vertical lift, the seat angle, and the contour of approach to the seat. The flat seat is adapted to open the largest area per unit of vertical lift and hence should be employed, other things being equal. Since the approach to a standard orifice makes the throat sectional area 100 per cent. efficient, the characteristics of such an orifice should be employed. Prof. E. F. Miller, of the Massachusetts Institute of Technology, was the first to round the edges of a safety valve to increase the efficiency of discharge per unit of lift, and in so doing took a long step in the direction of high safety-valve efficiency. The valve shown in Fig. 4, in which the standard orifice or, better, its practical equivalent is incorporated, follows the theory proposed by him several years ago. The full benefit of the standard orifice would be available regardless of the type of lip provided if the passage area from the seat outward increased, but to produce a high-lift valve the maximum available pressure between the lips consistent with maximum discharge must be used.

In a standard orifice the area of each section after the throat section is equal to that at the throat section, and it has been found that the pressure at the throat section and at each section of equal area thereafter is close to 0·6 of the boiler pressure, and that the back pressure into which this orifice discharges has no effect on either the weight discharged or the

* Abstract of paper presented at the Boston local section of the American Society of Mechanical Engineers, March 14th, 1916.

existent orifice pressures unless this back pressure exceeds 0·6 of the boiler pressure. If it does exceed 0·6 of the boiler pressure, the discharge capacity is reduced and the pressure throughout the orifice is increased. With an orifice of the shape shown in Fig. 5, but of equal throat sectional area, the weight discharged is the same as before, but the pressure after the throat section varies inversely as the area. It follows that to produce maximum pressure between the lips, there must exist at full lift an equality of area at each section outward from the throat of the orifice which is located at the seat. Since the effective disc diameters are constantly increasing, the effective lift must be reduced as the passage is lengthened. This can be done by giving the passage an upward slope, as is shown by Fig. 6.

If a valve of these characteristics is constructed and blown, it will be found to have an extremely high lift, and the opening of such a valve is so sudden as to be truly explosive. A very

FIG. 8.—PERFORMANCE OF 2½IN. EXPERIMENTAL VALVE.

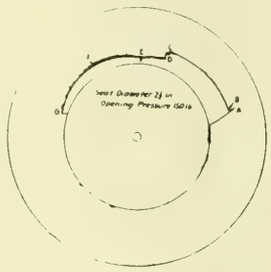


FIG. 10.—VALVE OF FIG. 8 WITH BLOWDOWN RING LOWERED.

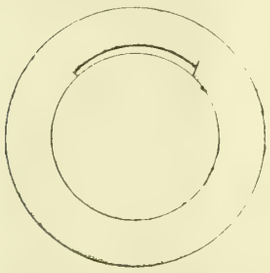


FIG. 11.—2IN. VALVE: SUSTAINED LIFT AND LOW CLOSING LIFT.

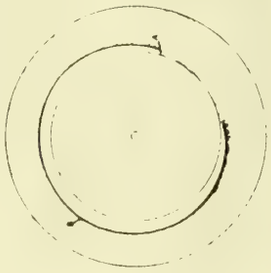


FIG. 12.—2IN. VALVE: LOW SUSTAINED LIFT, WITH PRESSURE ACCUMULATION.

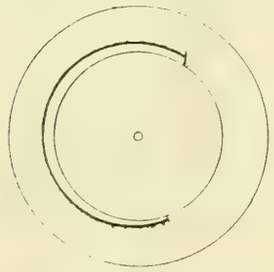


FIG. 13.—2IN. VALVE: PRESSURE ACCUMULATION BETWEEN OPENING AND CLOSING.

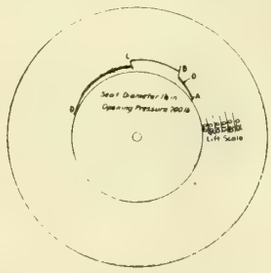


FIG. 14. A SECOND OPENING VALVE.

large percentage of the pop lift is sustained if the popping pressure is held constant, and when such a valve starts to blow down, the lift gradually decreases during the blowdown period until a certain point is reached where the pressure becomes such that the valve disc drops suddenly to closure. This construction will produce a blowdown which is likely to be a third of the boiler pressure and forces its designer to incorporate means of regulation which will give a small blowdown without interfering with the capacity or other features of valve action.

A valve that chatters or vibrates at the instant of opening or sizzles at that time shows a lack of lifting force at low lifts, and one that shows an excessive blowdown demonstrates that the lifting force at low lifts is too great to allow of closure, and it follows that the requirements of warning and blowdown are somewhat combative. Blowdown is an absolute necessity on the spring-loaded type, owing to the existence of lifting force outside the spring chamber, and it is clear that attempts to reduce the blowdown will tend to decrease the lift and relieving capacity. In general, the real secret in the design of a perfect safety valve lies, not in the production of excessive lifting force, but in controlling and adjusting it.

Fig. 7 shows a valve which has means for adjustment, based on the production of variable lifting force. The two annular rings A and B carry on their upper surfaces curves that approximate in shape the curve on the disc. The inner ring A, which may be called the warning ring, is threaded upon the base of the valve just outside the flat seat and carries threaded upon it the ring B, which is adapted to control the blowdown. These rings may be lowered away from the disc, or given initial clearance. If both of these rings are lowered an extreme distance, when the valve tends to open, no lifting force will be available; but if the ring A is raised to a position near the valve disc, a lifting force will be provided which will

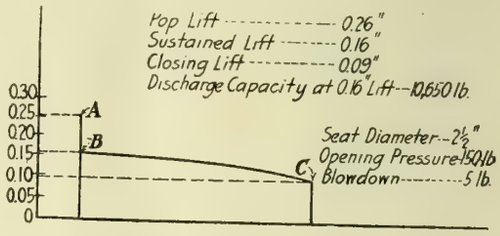


FIG. 9.—ANALYSIS OF DIAGRAM SHOWN IN FIG. 8.

depend, first, on the pressure produced between it and the disc, and, second, on the extent of the disc area on which this pressure acts. The pressure depends on the area of the passage, and the area in the valve is a function of the initial clearance, and the shape of the curve. As the blowdown ring B is raised from its lowest position, there is a tendency to build up pressure between it and the disc when the valve is open, which tendency increases as the disc is approached; and if a reasonably large clearance is left, this ring produces almost no lifting force at low lift, since the area of the passage along it is large in comparison to that over the seat. It follows, also, that as the disc lifts, the effect of this initial clearance on the area of the passage becomes less and less as lifting continues.

The author has succeeded in getting some diagrams from valves under service conditions which show in detail the results of the methods of regulation employed. The recording apparatus consisted of a clock motion adapted to turn a chart

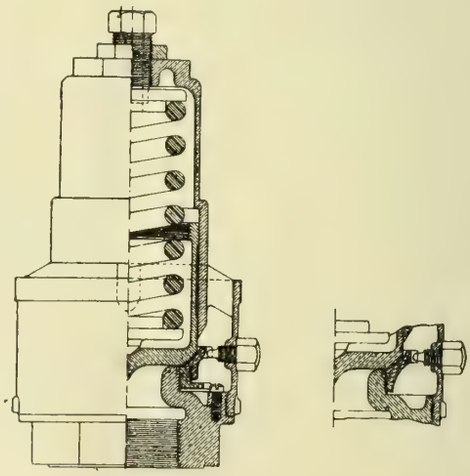


FIG. 15.—LOCOMOTIVE VALVE OF APPROVED DESIGN.

once in 15 minutes. Bearing on this chart was a pen rigidly connected to the spindle of the valve and adapted to leave a record thereon of lift with respect to time, the lifts being multiplied by a ratio of approximately 4 to 1.

Fig. 8 is a chart of the performance of a valve with a 2½in. seat. This valve was blown at 150lbs. gauge and showed under the existent regulation 5lbs. blowdown and almost no warning. That it may be clearly understood, it has been transferred to a diagram, Fig. 9, having rectilinear axes, on which is plotted the scale of lifts which resulted from calibrating the recording lift gauge with an accurate micrometer. The sudden pop lift is shown at A and the corresponding sustained lift at B. The variations in lift at B are further evidence of the readjustments of pressure which determine the pop and sustained lifts. The discharge capacity of this valve was such that the popping pressure was not maintained, and

the curve from B to C shows the reduction in lift, which in this type always corresponds to a reduction in boiler pressure. At C the valve closed suddenly with less than half its initial sustained lift prevailing.

Fig. 10 shows the same valve with its outside or blowdown ring lowered slightly. This, like the one preceding, is a photograph of the actual diagram and has not been transferred to rectilinear axes because of the difficulty in showing the fluctuations in lift.

It was decided after the two preceding diagrams were secured to change to a smaller valve of lower discharge capacity under which the pressure could be regulated as desired. The new rules, if put into force, will allow 6 per cent. accumulation of pressure, and the three next diagrams show what advantage may be taken of this accumulation.

Fig. 11 is a chart taken from a 2in. valve in which the pressure was not allowed to accumulate. The low closing lift in comparison to the sustained lift is to be noted. Fig. 12 shows the same valve with an accumulation of pressure over the opening pressure of 4 per cent.

In Fig. 13 the valve was regulated to give a low sustained lift and was then given the full 6 per cent. accumulation. The

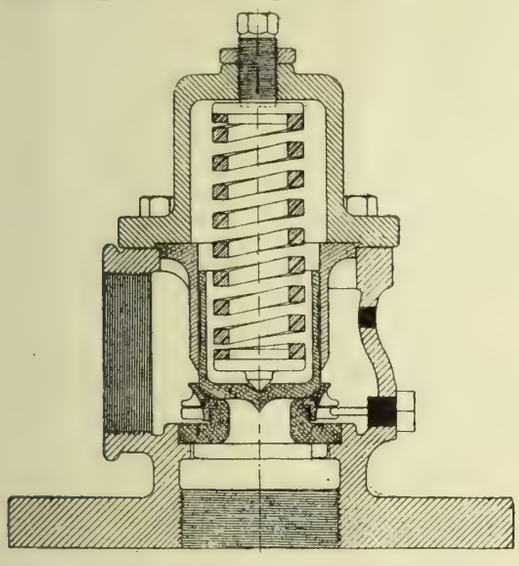


Fig. 16.—Steam Safety Valve of Approved Design.

discharge capacity at 6 per cent. accumulation is more than 100 per cent. greater than that at the opening pressure. The low closing lift is to be noted as before. The blowdown on this valve was about 2lbs., so that this chart was made between a maximum pressure of 159lbs. and a minimum pressure of 148lbs.

The diagram (Fig. 14) shows the characteristics of a safety valve that is absolutely new both in conception and results. It has been the aim of safety-valve designers to produce a valve which relieves a boiler with an action that is smooth and containing as few sudden fluctuations in pressure as is possible. The ideal safety valve for practical purposes is one in which a reasonably low lift is maintained at the popping pressure, but one which will on the slightest accumulation respond with an extremely high lift to take care of the emergency. If a low lift is available at the popping pressure for ordinary relief, a low blowdown may be incorporated, the condition imposed by absolute safety being that at slightly above the popping pressure the lift will have increased to such an extent that any possible emergency will be taken care of.

Fig. 14 shows a diagram from a valve that produces the above action and is what may be called a second-opening valve. Many of this type have been built, and it has been found that with the proper regulation of rings, all valves having two rings will produce this action in modified form. Imagine first, one of the ordinary type blown with the outside ring removed. This would result in a low lift and a very low blowdown. Now suppose that the blowdown ring is in place, but that it is given such a large initial clearance that the valve will act, if it has sufficient capacity to relieve the boiler, exactly as before, but if it has not the required capacity, the pressure will accumulate and the increase of lift resulting with only the inner ring in action will finally bring the outer ring into action and a second pop will occur. This pop will result in a high lift with corresponding high discharge capacity, and the valve size may be proportioned to give the required safety.

There is reason to believe that we shall soon have boilers that will operate at 600lbs. A 4in. valve set at 600lbs. will have a spring load of approximately 7,540lbs., or about 3¾ tons. If a 2in. valve can be constructed to give twice the lift of the 4in., it will have the same discharge capacity, but its spring load will be only one-quarter as great. In other words, the discharge capacity varies as the first power of the diameter and the lift, but the spring load, which is independent of the lift, increases as the square of the diameter. It seems clear

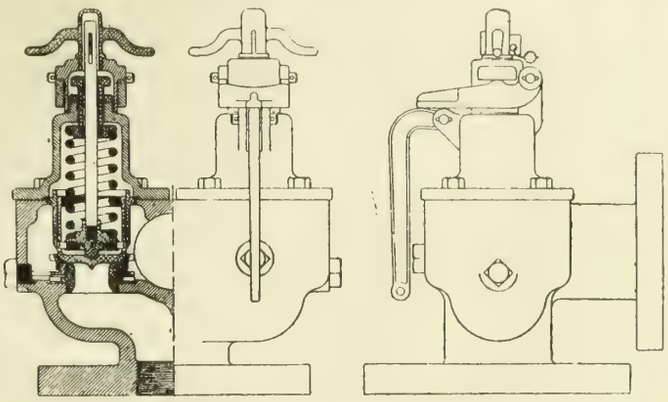


Fig. 17.—Marine Valve of Approved Design.

from this that high-pressure boilers will of necessity require small-diameter high-lift valves.

The effect of back pressure in the casing of a safety valve has been much discussed. It has been said that it may operate in two ways to reduce the discharge capacity, first, the effective lifts may be reduced, and second, it has been held that back pressure reduces the efficiency of discharge of the orifice. If any of the disc area is exposed to back pressure, the lifts will be reduced to some extent, but consideration of the theory of flow through an orifice, and particularly a standard orifice, brings out the fact that as long as the back pressure in the casing is less than 0·6 of the boiler pressure, the discharge of the orifice is not affected.

There are many economical advantages to be gained by a valve that will operate without harmful effect of back pressure. First, the sizes of discharge pipes may be reduced, and second, several valves may be connected into a common discharge pipe. Fig. 15 shows a valve that has the foregoing advantages. In the first place valves of high lift—and by that is meant higher lift than any of those obtainable at present—must be guided from above, as guides in the base will cause too great a drop in pressure on the disc area. In this view the disc is made in the shape of a hollow piston, which is guided

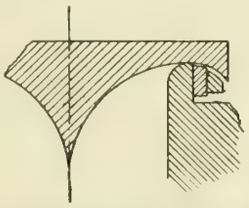


Fig. 18. Valve with "Jet Action."

by a cylindrical sleeve enclosing the spring chamber. The fit between these is extremely loose, and no attempt is made to prevent leakage by the disc. This loose fit ensures that the disc will not bind because of expansion or contraction between the members due to temperature changes, and is long enough in relation to the diameter of the disc so that it will never cock. Its looseness alone ensures that the disc will come to a uniform bearing on the seat, and it has been found that under no conditions of back pressure has the leakage by it been sufficient to produce pressure in the spring chamber, which is always fitted with a vent. With this type the back pressure may be built up to nearly 0·6 of the boiler pressure without hampering the discharge capacity, and since the back pressure is a result of the effective opening of the valve, it has no effect whatever on regulation if it is brought about by the means shown. In the case of duplex or triplex valves having a common discharge

pipe, the opening of one will tend to open the other, owing to the exposed area outside the seat and the impossibility of back pressure acting downward on the disc.

Fig. 16 shows stationary type and Fig. 17 the proposed marine type of exceedingly large capacity. It must be understood that the commercial types of valves shown in these illustrations do not depend on back pressure for any part of their action, but are in every case adapted to work with it, without harmful effect. Having shown a valve in which there is substantial increase in discharge capacity over those in use at present and having demonstrated that this may be accomplished with lower closing lifts than are now the rule, attention is called to a possible improvement in this type. The reader will have noticed that in all the types shown the passage turns upward from the seat region, and it is also clear that, so far as the area conditions go, it might as well be turned downward. If it is turned downward, the area conditions will remain constant, as illustrated by Fig. 18, but there will be available as lifting force a factor which would act upward in the disc and which is commonly known as a jet action. A few valves of this type have been constructed, and the results gained have been convincing of their possibilities. Enormous lifts have been attained with the same absence of shock at closure as with valves herein described. The problem has been by no means solved, but advances have been made in a direction that tends to indicate that it will be solved finally and will result in enormous discharge capacities per inch of valve diameter with the same efficiency per unit of lift. It is clear from a consideration of the diagram that the force due to jet action will not be destroyed by back pressure, as the velocity of the issuing jet of steam is a function of the orifice pressure, which pressure is not affected by the back pressure.

LIGHT AND ILLUMINATION.*

BY DR. CHARLES P. STEINMETZ.

ILLUMINATING engineering, that is, the art of producing light, is relatively one of the most encouraging branches of engineering, as it has in the last 10 or 15 years shown a wonderful progress in increasing the efficiency of light production many fold. At the same time, however, we may also say that in the field of producing light is met a discouraging branch of engineering, because in spite of the great progress made in economy of lighting, as illustrated, say, in the gas-filled "Mazda" lamp of to-day, the efficiency is still only about 4 per cent., and 96 per cent. of the energy consumed in the lamp is wasted. Although the efficiency is still low, nevertheless the advance from the days when the efficiency of light production measured a fraction of 1 per cent., compared with that made in the last 10 or 15 years, means that we can hope for still greater improvement in the future. A wide field for such improvement remains, and instead of producing 2 c.p. per watt, possibly 20 c.p. or more may eventually be obtained.

It should be realised that the artificial production of light for illuminating purposes is comparatively recent, much more recent than is generally understood. I remember, for instance, my grandmother telling me that when she was young, resinous pine sticks were their only means for lighting; that was not so very long ago, and not in the wilderness, but in a civilised country. In my time vegetable oils were also used to illuminate, and I remember the first kerosene lamps, and that they had the reputation of being dangerously explosive and required careful handling. Gas was the street illuminant.

Then came the electric lamp. I remember the first incandescent lamp tried in my native city for street lighting, early in the 80's. I do not know whether it was a 50-volt or a 100-volt lamp. It was a small affair, giving a comparatively dull reddish yellow light not especially attractive. The first arc lamp there, however, was very different. Its exhibition was one of the startling features; the whole city, about the size of Washington, came to see the remarkable illuminant. All those things—incandescent lamps, arc lamps, even kerosene lamps, all our illuminants—are still within the memory of living generations. The whole field of lighting is really so new that only a very few generations back there was practically no artificial illumination applicable for general use.

In view of the progress of the art, within two generations, turning night into day, as it were, for useful work, we can imagine what future generations may accomplish, when we consider that there is still such a vast field for further improvements in efficiency.

Artificial light has always been produced by heat, first, by the heat of combustion, by burning pine sticks, vegetable oil, coal-oil, kerosene, gas, &c.; and, second, when the electric light came, in the same general way by heating the incandescent filament or the tip of the arc lamp carbon to a high temperature by means of the electrical energy put into it. Heat is produced in all these methods of lighting, and a small part of the heat comes out as light. The light is practically a by-product of the heat generated.

The first real advance beyond this way of obtaining light was made by Auer von Welsbach, who originated, in the Welsbach lamp, a method of lighting not dependent directly and wholly upon heat, but giving an illumination many times greater than any merely incandescent body would give at the same temperature. That was the first step toward a different method of producing light, a method that holds out a promise of possibility of efficiency greater than in producing light through temperature, that is, solely by heat.

To understand the subject better, let us first consider what light is. If a spring is slowly and regularly vibrated away from a contacting stop, we hear the stroke of each individual vibration. By moving it faster and faster until the frequency, or rate of vibration is about 30 per second, the ear will no longer distinguish the individual vibrations; they would run together, and blend into a continuous note, the deep bass C. If the spring is moved still faster, we would continue to hear a continuous note, of a higher pitch, however, corresponding to the particular rate of vibration.

This result can readily be accomplished by means of a star wheel arranged to rotate at any desired speed up to a very high rate, the teeth of which strike against a flat spring. For instance, if the speed be such as to obtain 250 vibrations per second, they are heard as a note in the middle C; and if the speed goes on increasing, we successively distinguish the notes D, E, F, G, A, B, and finally, at 500 vibrations, the next higher C of the musical scale, or C in the next higher octave. If the rate of vibration be decreased from 250, from middle C, down to half as many, or 125 vibrations per second, we hear the bass C, the C of the next lower octave.

So you see there is a definite scale for the frequency of vibration embraced in the octave, which, however, was originated long before people knew musical notes were the result of vibrations. And a system for the various frequencies of sound vibration has been established in the musical scale in which the octave is the unit. The octave changes from two to one; every time the frequency of vibration is doubled the same note of the next higher octave is produced; if the frequency is decreased to half, the same note of the next lower octave results.

But there is a limit to the ability of the ear to take cognisance of vibrations. Going from low to high and still higher vibrations the ear hears them progressively as musical notes of higher and higher pitch, finally becoming a screechy noise, no longer musical, when the rate reaches thousands of vibrations per second, and eventually a limit is attained generally between 6,000 and 8,000 vibrations, when the ear ceases to hear them, although sound waves are still being set up in the air and impinge upon the ear. The rate of vibration at which hearing stops is not the same with everyone; different persons hear higher up or lower down in the scale; but in general the range of frequency of vibration which can be heard as continuous sound or note is from about 30 vibrations per second, the deepest bass, up to 6,000 to 8,000, the highest pitch, embracing, say, six to eight or nine octaves.

Now suppose we go still higher in frequency, not in thousands but in tens and hundreds of thousands, and even up to hundreds of millions of millions of vibrations per second. We can then again perceive them with our senses, not, however, with the ear as sound, but with the eye as light.

Naturally vibrations at the rate of hundreds of millions of millions per second cannot be produced by any mechanical device, as the star wheel before mentioned; no body can be moved quickly enough to accomplish it. Moreover, the air cannot be utilised to transmit such rapid waves, because air, however thin it may appear to us, is altogether too dense and

* Paper presented at a joint meeting of the electrical section of the Western Society Engineers and the Chicago section of the American Institute of Electrical Engineers, October 26th, 1915.

heavy a body to move so rapidly. Such extremely rapid vibrations have to be transmitted by a medium infinitely thinner and lighter than air, the universal ether, which is supposed to pervade all space and all matter and transmits these very high frequency waves, some of which we can see as light.

When the rate of vibration of this ether is about four hundred millions of millions per second, the eye begins to see it as dark reddish light. At progressively increasing frequency we see it successively as orange, yellow, green, blue, and violet light, until the rate reaches seven hundred millions of millions, when its effect upon the eye ceases and darkness ensues. There is, however, a frequency of vibration of the ether far beyond this, hundreds of times faster than the frequency of light. What we know as X-rays are perhaps the ultimate result of exceedingly rapid vibrations, amounting to many thousands of millions of millions per second.

We have seen that there is a range of vibration up to 8,000 per second perceptible to the ear, the air transmitting these comparatively slow vibrations as sound. Then there is another range of vibrations up in the hundreds of millions of millions transmitted by the ether, which the eye perceives as light. The range of frequency of sound waves is very wide, embracing about eight or nine octaves; but the range to which the eye is sensitive is only from about four hundred millions of millions to seven hundred millions of millions, relatively less than one octave. That is, the fastest vibrations which the eye can see are less than twice the slowest ones. Therefore, as regards the range of frequency of vibration the eye is much less sensitive than the ear; the eye perceives less than one octave, while the ear is sensitive to over eight octaves.

Now let us consider ways of producing sound waves. When one body is hit by another, say, by striking the table with a hammer, we hear a sound. Energy is expended by the blow and produces a mixture of vibrations of many different frequencies with no fundamentally predominating and controlling frequency, which are communicated to the air; the different frequencies result in a mixture of corresponding notes that are discordant or disagreeable in the musical sense, and thus we call such a sound a noise. Other noises, because produced by other different mixtures of vibrations of many frequencies, result from dragging a stone over a rough surface, permitting air under pressure to escape from a nozzle, swishing a whip through the air, &c.

Suppose instead of striking the table with a hammer, I strike a stretched steel wire, for instance, one of the wires in a piano. What is the result? The wire can vibrate as a whole at only one definite fundamental frequency, which determines the pitch of the note produced. It is true that superposed upon this vibration there may be others of a greater frequency, but, when present, they are so secondary to the fundamental wave as only to affect its shape in a minor degree, to the extent of determining the timbre or quality of the note and not its pitch, and do not cause a musically discordant result, that is, the vibration of the wires does not merely make a noise. It is, then, not able to vibrate like the table with a heterogeneous mixture of discordant vibrations of all kinds of frequencies with no controlling frequency, producing only a noise; the wire vibrates at a particular frequency, and the resulting sound will be a note, which, of course, is a noise in the most general sense, but not in the musical sense.

If, for another illustration, instead of making a noise by dragging a stone over a rough surface, I drag a bow across a violin string, the energy communicated will make the string move, but being able, like the piano wire, to move only at one particular rate of vibration it will produce a definite note, the particular note obtained depending upon the length of the string and tension upon it.

Again, take the case of an air blast escaping from a nozzle with a hissing noise. If I properly place a tin tube over the nozzle, the air in the tube will vibrate, but, like the piano wire, at some particular frequency depending upon the length of the pipe; thus the air blast can no longer cause an adventitious mixture of vibrations, but only that particular one which the pipe permits, and we get a definite note.

So you see we can create a noise by any sort of impact, but to get a definite note, that is, a noise produced by a definite frequency, the body which is set in motion must be so shaped that it can move only at one definite fundamental rate, like the violin string or the stretched piano wire or the air column in the pipe.

The art of creating and making musical instruments has always been to shape the material so as to get waves of vibration of definite stable frequencies and shape, the shape giving the difference in quality, colour, or timbre of the notes of the different musical instruments. There must also be a rational method of supplying energy for producing such vibrations, by a felted hammer, as in the piano, or a bow, as with the violin, otherwise only a jarring noise is likely to result.

Analogous methods can be applied to obtain vibrations of the ether millions of millions times faster than sound waves, and which the ear cannot hear but the eye can perceive. If we put energy into a body by heating it, the body will send out ether vibrations at this higher rate. The collective vibrations thus obtained, translated into the language of sound, would be a noise, a mixture of waves of all kinds of vibrations with no particular fundamental frequency. If we heat the body to incandescence the same result is obtained. Now some of the waves, those which happen to be in the three-quarter octave, will be visible to the eye; while others in this ether noise, this mixture of vibrations, may be too fast or too slow to be seen.

Let us see how we can get some definite rate of vibration, some definite frequency of light. To get a definite frequency of sound you have seen that the vibrating body, the violin string, the piano wire, or the organ pipe, must be properly proportioned. For example, to get with an organ pipe a vibration of, say, 250 per second, the pipe should be about 4ft. long, because a column of air that length is able to vibrate at the required rate. But if the vibration is to be at the rate of five hundred millions of millions of cycles per second, which would produce a greenish-yellow light, naturally the body to be moved at that rate must be extremely small.

Now the smallest body which is available is the chemical atom. In a piano, when a particular note is to be sounded, the key corresponding to the wire having the correct length and tension is struck. But we cannot strike each individual atom of the steel wire separately. It is much more difficult to get a single atom into vibration by putting energy into it than to get a piano wire, violin string, or a column of air vibrating, because we cannot act upon each vibrating atom directly, but only on a big mass of them.

Atoms can, however, individually be set in vibration by various means. If an electric current is sent through a gas or vapour under low pressure in a vacuum tube, the individual atoms are set in vibration, and move with their own definite frequency, just as do the violin string or the piano wire, and give out, not an atomic noise, so to speak, but atomic notes of definite frequency. But while the violin string gives one frequency only, one note to the single string, we know now that the so-called chemical atom is not a simple thing, but has a very composite structure, and that it does not give a single note, but quite a number of different notes, corresponding in a measure to the sound produced by simultaneously striking a number of piano chords.

The chemical atom, therefore, gives a mixture of vibrations, not, however, as we get in noise, a mixture of all kinds of heterogeneous vibrations, but a definite number of separate definitely related vibrations, a so-called spectrum, representing the vibrations that the different components of the atoms, whatever they may be, are capable of producing. There may be a very great number of different vibrations, but with some materials we find in the visible three-quarter octave six different notes or colours, six different prominent vibrations constituting a spectrum of light, besides a number of lesser prominence and many more outside the visible range. These atomic vibrations are very complex, and the method which is very successful in producing definite simple vibrations of sound waves at low frequency, absolutely fails when we come to the high frequency of light. The best we can do with the atoms of gas or vapour is to get a definite number of distinct and related vibrations.

We can produce a noise, or all kinds of vibrations, at the high frequency of light, for instance, by heating, just as well as it can be done at the low frequency of sound by impact. And atom-noise is really what is wanted for lighting. A

definite frequency is undesirable; for example, a light which had only one definite frequency, say, the frequency of five hundred millions of millions, would be greenish-yellow, and would show everything of one colour. Therefore, at least for general lighting, a mixture of frequencies is needed—what in sound we call a noise.

In the range of sound for many purposes—for signalling, drawing attention, &c.—a noise is generally just as good as a note. What we are after is volume of sound, regardless of whether by a noise or a single note, but in lighting what is wanted is really a noise. In sound waves the range generally perceptible is eight octaves; practically any mixture of frequencies in making a noise will usefully fall in the audible range, and very little will be wasted. But in a mixture of frequencies of hundreds of millions of millions of cycles of light waves the visible part is only three-quarters of an octave, and in such a mixture a considerable part of the vibrations is sure to fall outside the visible range, and become wasted as light. Thus the difficult problem of producing useful light is not only to produce all kinds of frequencies of vibration, but to produce as large a part of them as possible within the three-quarter octave that can be seen.

A most convenient method of producing frequencies of millions of millions of cycles is by heat, by raising the temperature of the body that is to radiate the vibrations. A steam heated radiator will send out vibrations at the rate of many millions of millions of cycles, but they will be just a little too slow to come within the visible three-quarter octave and are thus not perceptible to the eye.

Most of the vibrations from aluminium at the melting temperature, probably 99·75 per cent., are too slow to be visible, but a very small percentage have a high enough rate to be just within the visible range, where the eye perceives them as red, orange, and yellow, with possibly a trace of green. The general result is a dull red orange colour.

At a higher temperature higher frequency radiations are obtained. At the temperature of melting iron more than 99 per cent. of the vibrations are too slow to be seen; most of them appear in the lower end of the three-quarter octave, as red, orange, and yellow, with some green, a few blue, and still fewer violet radiations, the colour mixture appearing nearly white. In the visible three-quarter octave the slowest vibrations appear red and the fastest are violet, and from the fastest to the slowest throughout the visible range the colours are successively red, orange, yellow, green, blue, and violet, just as we have the octave of sound waves divided into notes, C, D, E, F, G, A, B, and the next C. The next C has no equivalent in light, that is, in passing over the visible spectrum from red to violet, red is not repeated again beyond the violet, the spectrum of vibrations continues on, however, beyond the violet into an invisible region known as the ultra-violet.

At a still higher temperature, for instance, the temperature of melting tungsten, the percentage of frequencies of vibration that come within the three-quarter octave increases to 5 or 6 per cent. We get red, orange, yellow, considerable green and blue and some violet. The considerable increase in the number of higher frequencies in the blue and violet parts of the three-quarter octave give a mixture which produces almost a white light, much whiter than in the case of melting iron.

If the temperature is raised still higher, say, to about 5,000° C., 9,000° Fah., about 10 or 12 per cent. of the total frequencies will fall within the visible three-quarter octave. The highest efficiency of light production by heat would be at about 5,000° C., about the temperature of the sun.

(To be continued.)

STEEL DRIVING BELTS FROM THE SAFETY POINT OF VIEW.

AN article in "Dinglers Polytechnisches Journal" and translated in the "Journal of the American Society of Mechanical Engineers" discusses the comparative dangers of leather and steel belts. That steel belts may be used to advantage under certain conditions there is scarcely any doubt, but whether they are more or less dangerous than leather belts, especially in transmission between two floors, is still a mooted question. Assuming now that two belts, one a leather one and the other a steel one, run as shown in Fig. 1. Let both break on the lower side. What will happen? The leather belt, because of its weight and flexibility, will let its free end fall down. Then, as the pulley is still running, the belt will continue to move and its ends will describe an extended arc. This throwing apart of the ends of the belt can become a source of very considerable danger for the man on the lower floor, especially if the belt fastening is at one of the ends of the broken belt, which is very likely to happen, because that is where belts usually break. In Fig. 2 the leather belt is shown broken in its tension or upper side. In this case the entire belt is thrown violently away from its pulleys, and may easily become entangled in the running machinery.

As to the steel belt, it may be assumed that its weight is only about one-eighth that of a leather belt designed for an equivalent transmission of power; hence the centrifugal force of a steel belt is correspondingly smaller. The instant the belt breaks the tension necessary for the transmission of power is lost, the belt has a tendency to occupy a position in a plane, becomes free of the rotating pulley and falls flat. It is, therefore, unlikely that a steel belt can do any harm if broken. The likelihood of a steel belt inflicting bad cuts is over-estimated, and can be reduced by rounding its edges. The contact with the running steel belt may become dangerous if the belt runs at a very high speed, but contact with a leather belt is likewise dangerous, and both should be protected by proper guards. Perforated steel belts have the additional advantage that one can see at a glance that the belt is running.

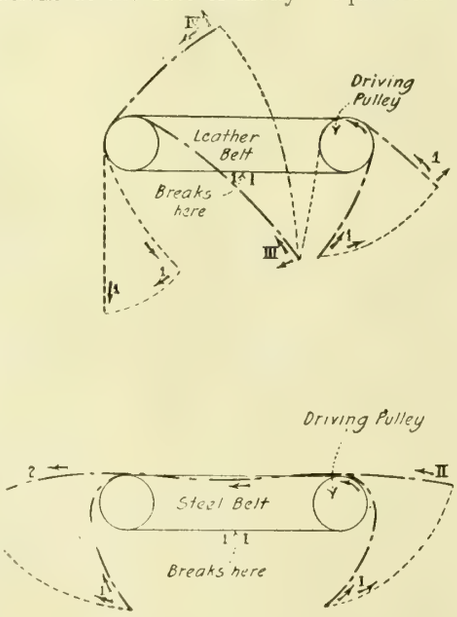


FIG. 1.

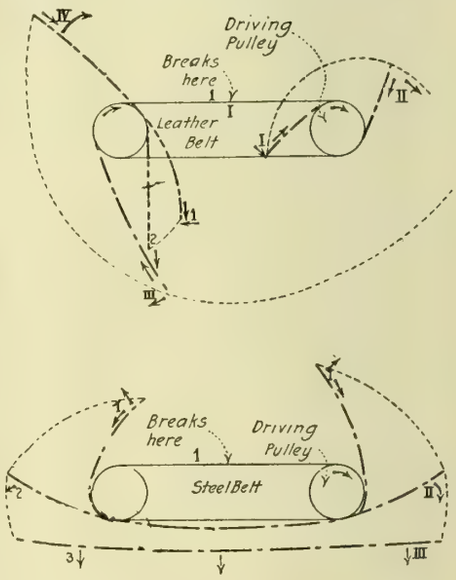


FIG. 2.

DIAGRAMS SHOWING THE DIFFERENCE IN THE WAY OF RUPTURE OF STEEL AND LEATHER BELTING.

Because of its lack of stretching, it is practically impossible to put on a steel belt while the shaft is running, which automatically eliminates one of the sources of accidents in belt operation, and also limits the field of application of steel belts to operations where it is not necessary to shift the belt very often. For this reason steel belts are not adapted for use on step pulleys. Besides, as the steps on the pulleys are seldom in precise correspondence with each other, the steel belt, because of its lack of ability to stretch, is inadaptable for this kind of work. In engine lathe work, where men are accustomed to shifting the belts from one pulley to another by hand, a steel belt would not do at all. The author concludes that the steel belt is no more dangerous than the leather belt.

THE DESIGN OF HIGH-PRESSURE DISTRIBUTION SYSTEMS.*

BY J. R. BEARD, M.SC.

The general distribution of electrical energy to individual consumers at high pressures is of comparatively recent development, one of the first schemes in this country being that which was inaugurated in the year 1901 for the purpose of supplying power to shipyards on the Tyne, and which has since grown into the extensive system that now covers the principal industrial districts of Northumberland, Durham, and North Yorkshire. High pressures had previously been used, but only for transmission purposes to enable the power stations to be situated outside the areas of supply in order to utilise special advantages such as waterfalls, cheap sites, plentiful condensing water, or easy delivery and storage of coal. In such cases the high-pressure energy was transmitted to a point near the centre of the area of supply where the whole of it was transformed to low pressure for distribution to the consumers. Such schemes, for example, were Dr. Ferranti's pioneer high-pressure transmission from Deptford to London, and various water-power schemes in America and on the Continent.

The advantages of supplying concentrated power loads of, say, 100 kw. and over direct from the power station at high pressure and transforming to the working voltage at individual sub-stations adjacent to the load centres, have since been generally realised, and the last decade has seen an enormous development both in the number and in the size of such high-pressure distribution systems. Side by side with the development of high-pressure distribution for power purposes, similar methods were found essential for the various railway electrification schemes, and also for the supply of power to the larger tramway systems which were spreading out over an area that it was impossible to supply at low pressure from a single power station. Up to the present the method of distribution for lighting has not been radically altered, although occasionally the existence of a high-pressure distribution system, primarily installed for other purposes, has resulted in bulk supplies being given to outlying districts. It is, however, being more generally realised that only under exceptional circumstances is it possible to find near the centre of a large lighting load conditions which permit of economical generation, and consequently the original Deptford example is being more widely followed. In many such cases owing to the ease with which a sub-station — unlike a power station — can be installed in almost any position, there is a growing tendency to split up the more extensive and cumbersome low-pressure networks into several sections, each fed by a separate sub-station. As the use of electricity for lighting and other domestic purposes increases, there is little doubt that these sections will gradually decrease in area, with a consequent increase in the number of high-pressure feeding points, so that in this, as in other branches of electricity supply, the distribution will eventually be at high pressure practically to the consumer's terminals.

Not only is the cost of distribution at high pressures considerably less than at low pressures, but also it is thus possible for a single power station to supply economically over an enormously greater area than that which was previously practicable, and in consequence by better diversity factor and larger and more efficient generating plant great reductions have been effected in the cost of electricity. The maximum economy from these advantages is still far from being obtained, and there is therefore every prospect that in the future the growth of high-pressure distribution systems will be equally as rapid as it has been in the past. The growth should, however, be in size and not in number, since in order to reap the full benefit of improved diversity factors and increased efficiency of generation it is essential that each system should supply the whole of the demands of the area which it serves, and also that the area served should be as large as possible.

The term "distribution system" is often used in a broad sense to indicate everything outside the power station, but in the present instance it will be restricted to mean the mains which convey the electrical energy from the power stations where it is generated to the sub-stations where it is transformed to a form suitable for the consumers' use, together with the switchgear controlling them. The paper will further be limited to a consideration of 3 phase alternating current systems, as it is generally recognised that these are most suitable for high pressure distribution.

General Principles. A well-designed distribution system is that which secures the following essential characteristics at a minimum total annual cost: (*a*) Safety in operation both as regards the operating staff and the public generally. (*b*) Suitability of the supply for the purposes for which it is required. (*c*) Freedom from interruption of supply.

Safety in operation is of primary importance, since with high pressures accidents are frequently fatal and, in this country at any rate, no commercial advantage is considered sufficient to justify unnecessary danger to human life.

The other two limitations have a commercial basis. In all its various uses electricity is a competitor with other forms of energy, many of them very firmly established, and if it is not supplied in suitable form, or if the supply is subject to interruption, the sale of it will be restricted. For example, the cost of power is such a small proportion of the total cost of running a works that material irregularity in the supply would quickly involve more loss than the whole cost of the power bill. In such circumstances a supply of electricity would not be a paying proposition if it could be obtained for nothing.

Failure of supply is usually caused by the breakdown of apparatus, and the primary precaution is therefore careful attention to the design, manufacture, and maintenance of the various parts of the system; but since no apparatus can be made absolutely immune from breakdown through external damage, the secondary precaution is to make arrangements so that the effects of a breakdown to any part of the system are localised as much as possible. In some cases such precautions may mean increased capital cost, but they undoubtedly result in a net economy if a broad view is taken. Fortunately, however, well-designed apparatus does not necessarily cost more than badly designed apparatus, and, as will be seen later, it is possible to cheapen the system by closer localisation of breakdowns.

The chief items which make up the annual cost are the following, and it is the sum total of these which should be a minimum: (1) Interest on capital expenditure. (2) Repairs and provision for depreciation. (3) Switchgear attendance. (4) Energy losses in the mains.

It may be useful to consider briefly these items in turn, and to note in what ways they are interdependent and how they are affected by the essential characteristics previously detailed.

(1) It is unnecessary to say anything as to the desirability of keeping down capital expenditure; the chief danger is usually lest this point should receive too much attention at the expense of other items. There is, however, a further way of reducing interest charges, namely, by a low rate of interest, and this can only be secured by a permanent and steady business. This is a further argument for extending and consolidating the area of supply so that the revenue of the undertaking is less subject to trade fluctuations.

(2) A low cost of repairs goes hand in hand with low depreciation charges, since both depend on the permanence of apparatus and its freedom from breakdown. Money is doubly well spent on these points, since it not only reduces repairs and depreciation, but provides the first precaution already postulated as necessary to ensure security of supply.

(3) Particularly in the case of static sub-stations, which have not an operating staff continually on shift, attendance is largely a matter of operating switches should a fault occur on some part of the system. Apart from cost, such attendance is often very difficult to arrange for, and there is therefore a strong reason for reducing it as much as possible. This can be done by closer localisation of breakdowns so that the only part of the system which is affected is that in the immediate neighbourhood of the fault, thus at the same time taking the second precaution postulated as necessary to ensure security of supply. The cost of attendance is not only a question of amount but also of quality, and cheaper labour can be employed if apparatus is designed to prevent automatically the more serious mistakes in operation. Such design tends to increased safety in operation, which has been previously mentioned as the first essential characteristic of the system.

(4) Loss of energy in the mains can be reduced by increased capital expenditure, and it is therefore a question of the

* Paper read before the Institution of Electrical Engineers.

correct balance between the two. It can also be reduced by linking up the various parts of the system in order to utilise the diversity of their loads, a process only rendered possible by again using means for localising the effects of breakdowns.

It is interesting to note that the essential characteristics of the system are not incompatible with designing it on the basis of minimum annual cost, since though they may in a few cases increase the capital expenditure this is discounted by savings in other ways.

The object of this paper is to endeavour to indicate on the basis of the preceding general principles the most suitable choice of apparatus and the means whereby that apparatus can be used to the greatest advantage. For this purpose the paper will be divided into the following sections:—

I. The important points in the choice of individual apparatus: (*a*) Mains. (*b*) Switchgear.

II. The methods by which such apparatus may be most economically utilised, the consideration of which naturally falls into three successive stages. The basis of the investigations is: (*a*) The determination of the economical section of mains; that is to say, the correct balance between losses and capital expenditure.

From this it is possible to consider progressively: (*b*) The lay-out of the distribution system to give the maximum economy. (*c*) The most suitable distribution voltage.

I. (*a*). **Mains.**—As it is desirable to avoid covering ground which has been recently covered by other papers read before

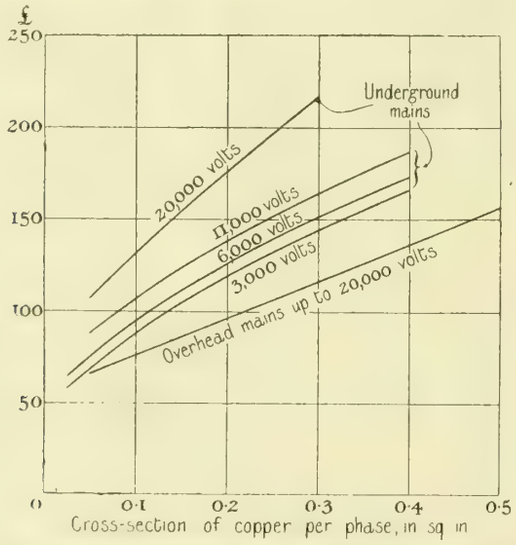


FIG. 1.—ANNUAL COST PER MILE OF INTEREST AND DEPRECIATION FOR VARIOUS TYPES OF 3-PHASE MAINS.

the Institution, this section of the paper will be limited to a brief consideration of the conditions which determine whether underground or overhead mains are most suitable for particular cases. Both have reached a high degree of perfection, but owing to the fact that the conductors are exposed, overhead mains are necessarily more subject to breakdowns than underground mains, so that from the point of view of security of supply the latter are to be preferred, unless special circumstances such as liability to serious subsidence increase the risk of damage to cable. This point is, however, not so important as might be thought, since in spite of the numerous ways in which overhead mains can be damaged by snow, wind, lightning, malicious damage, and short-circuits due to birds, flying straw, kite strings, &c., it is found in practice from extended experience that per mile of main the average number of serious breakdowns of overhead mains is only about double that on underground mains. Overhead mains are, however, more liable to cause temporary interruptions of supply by being automatically disconnected on transitory short-circuits which do not cause permanent damage. The advantage of overhead mains is their lower capital cost, more particularly at higher voltages; this is readily seen by glancing forward for a moment to Fig. 7, which shows comparative annual costs per mile for various voltages, allowing a slightly higher figure for the maintenance of overhead mains and including a reasonable figure for wayleaves. For low voltages and small sizes there is not much to choose on the score of cost, and underground mains are therefore preferable on account of their other advantages. As the voltage and size increase, however, a considerable saving is effected by the use of overhead mains; and such saving is often increased by the difficulty in finding direct routes for cables in the open country where roads are few and winding.

While it will be seen from the foregoing that the use of overhead lines in open country is frequently fully justified, they have further disadvantages which must always be borne in mind, viz.: (*a*) They usually require a special wayleave. (*b*) The inductive drop is much greater than that of an equivalent cable. (*c*) If overhead lines are run in parallel with cables neither can be operated at their maximum economy. (*d*) They tend to lower the power factor of the system as a whole.

(*a*) The objection to wayleaves is not so much their cost as the trouble and delay in obtaining them, and the fact that they can seldom be bought outright. The anomalous and conservative provisions of English law in this matter have been recently discussed both by Mr. Welbourn in his paper on high-tension overhead lines and by Mr. C. Vernier in his address to the Newcastle Local Section, and the matter had also been previously raised by Mr. W. B. Woodhouse as a result of his experience with the Yorkshire Electric Power Company. When a suitable time arrives the need for the legal changes which they advocate should not be lost sight of.

(*b*) The inductance of a 3-phase circuit, other factors remaining constant, varies as the logarithm of the distance between the conductors; the higher inductance of overhead lines is therefore inherent in their construction, since this distance must be many times the corresponding distance in a cable, owing partly to the lower insulating value of air as compared with impregnated paper, but more particularly to the necessity for preventing the wires being short-circuited by birds, or by unequal swinging due to wind, or by unequal sagging due to snow. This higher inductance does not affect the voltage-drop when the power factor of the system is not a lagging one, but it is unusual for the amount of synchronous plant on the system to be sufficient to ensure this. The question of voltage-drop is dealt with more fully in a later section, but by reference to Fig. 10 the increase in voltage-drop at 50 cycles with various lagging power factors is clearly shown.* It will be noted that it is quite serious, particularly in the case of heavy-section lines, and consequently the use of overhead mains means either a reduced radius of transmission for a given voltage, or extra capital cost in providing additional copper. To some extent this disadvantage is minimised by the fact that for economy overhead mains should be run at a lower current density than cables (see section on the economical section of mains and Fig. 6), and also by the fact, noted previously, that it is often possible to carry overhead lines over a shorter route than the equivalent cable.

In certain special cases the inductance of overhead mains may be of definite benefit. This is, for example, the case in continuous-current traction systems supplied by rotary converters which can be arranged to draw a leading current from the line at heavy loads. It will be seen by again referring to Fig. 10 that with quite a moderate leading power factor the total voltage-drop in an overhead line feeding a rotary converter sub-station may be zero.

(*c*) If a cable and an overhead line of equal section are connected in parallel the higher inductance of the overhead line causes the total current to divide unequally between the two circuits. This not only prevents the two circuits being run at their most economical current density, but also, owing to the resistance losses being dependent on the square of the current, they are greater than if the current were divided equally. Further, owing to the difference in the inductance of the parallel circuits, there is a phase difference between the currents in the two branches. This results in the arithmetical sum of the currents in the branches being greater than the total current, thus causing additional resistance losses and a reduction in the carrying capacity of the circuits. To take a concrete example, assume that 300 amperes at 6,000 volts and 50 cycles is to be transmitted through a 0·15 sq. in. cable and a 0·15 sq. in. overhead line in parallel. The actual current in the cable will be 210 amperes, and in the overhead line 105 amperes, while the resistance losses are increased by 24 per cent. as compared with the losses if both circuits were either cable or overhead line.

* The curves given in Fig. 10 are calculated for ordinary 3-conductor mains. If arranged for split-conductor protection the inductive drop is reduced.

(*d*) It is at once evident that, so far as the power station and the mains back to the power station are concerned, the wattless current produced by the extra inductance of an overhead line will be as deleterious as if it were produced by consumers' apparatus.

I. (*b*). **Switchgear.**—The following remarks are directed to the more important or novel features which should influence the choice of the most suitable apparatus for sub-station use. Similar principles apply, but with greater force, to power-station switchgear.

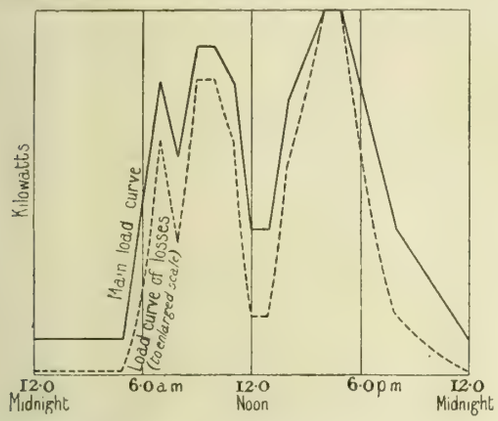


Fig. 2.—Load Curve of Typical System with 50 per cent. Load Factor and Corresponding Curve of Losses (to enlarged scale) with a Load Factor of 35 per cent.

Switchgear fulfils several functions, but the primary one is to isolate faulty apparatus, and consequently to interrupt or prevent heavy short-circuit currents. This is the determining factor in its design. The problem is therefore one of considerable difficulty, since it is largely beyond mathematical calculation and the chief data to work upon are those obtained from actual experience. With many problems great assistance can be obtained from experiments, but this is difficult with switch design, as the conditions cannot be adequately reproduced on a small scale, and it is not usually commercially practicable to risk experiments on an actual system.

As the tendency is for distribution systems to supply a denser load it follows that the maximum short-circuit current is continually increasing; for not only is there a larger kilowatt capacity of running plant on the system, but also a greater number of feeds into a fault. Moreover, the conditions are further aggravated by higher distribution voltages, without any corresponding reduction in the resistance of the faults. It therefore follows that switch design is a gradual process of feeling one's way; methods which have given good service on one size of system being tried on a larger one and modifications introduced if the more onerous conditions show up weaknesses.

The breaking of a heavy short-circuit can be best likened to the detonation of an explosive, and if the switch is badly designed the tank will be blown off and the whole switch wrecked. This was at one time thought to be due to the large quantities of white-hot oil vapour generated by the arc rising to the surface, and spontaneously igniting on meeting the air. It has, however, been proved by experience that a switch designed to withstand the maximum explosive pressure of the gases may be unable to withstand a short-circuit with unlimited power behind it, and it now seems probable that the chief explosive effect is to be found in the rapid generation of gas beneath the surface of the oil. Switches for heavy duty are usually designed with air cushions and vent pipes open to the atmosphere in order to remove the gases, but these measures do not materially relieve the pressure in the tank, as apparently the inertia of the liquid causes an exceedingly high local pressure which is transmitted hydraulically to all parts before the oil has an opportunity to move at its free surface. It is therefore necessary either to reduce the intensity of the explosion or to build the switch strong enough to withstand it. Since it becomes an expensive matter to build a switch to withstand a pressure of many hundreds of pounds per square inch the former alternative has received much attention. If the arc can be drawn out more quickly it follows that, other things being equal, extra resistance is introduced and the circuit is more quickly broken, thus cutting down the rate of heat generation and limiting the period during which it is being generated. Recent practice consequently tends towards quickening the break by decreasing the inertia of the moving parts and by accelerating their movement by means of powerful springs. Attempts have also been made to use the magnetic forces of the current for this purpose, since such an arrangement has the advantage that the more severe the short circuit the greater is the speed of break. One of the most interesting suggestions in this connection is that of drawing out two arcs electrically in series, but arranged parallel close to each other in opposite directions, so that there is a repulsive effect between them proportional to the product of the currents in the two arcs, that is to say, proportional to the square of the current. As the mass of the vapour carrying the current is so small the repulsive force will produce very rapid outward movement of the arcs in opposite directions, thus causing them to lengthen, which is in addition to and superimposed upon the lengthening due to the separation of the contacts.*

Perhaps the most obvious way of reducing the violence of the explosions is to cut down the short-circuit current by reactance coils. Except in connection with generators the use of these coils is attended by many disadvantages, as pointed out in the discussions on the recent papers read before the Institution on this subject. In any case it does not seem the correct procedure to use measures of a palliative nature at the present stage of switch design, since if there is one statement which can be made with more certainty than another it is that successful design has not reached its ultimate development. If used at all reactance coils should only be looked upon as an extra precaution kept in reserve to deal with unforeseen difficulties.

Switchgear is the most vital part of the system, because a fault on any part from the bus-bars to the far side of the switches is a bus-bar fault which will not only shut down the sub-station concerned, but will also seriously derange the whole system, since even if it were possible automatically to isolate the particular sub-station all the "through" connections at the sub-station would be interrupted. In practice the only means of circumscribing the effects of a bus-bar fault are to divide the system into a large number of isolated networks, thereby involving uneconomical working, or to divide the system into sections by means of graded overload gear, which latter can seldom be relied upon to discriminate properly. It is accordingly imperative to make the switchgear a sound job, and any saving in capital expenditure is dearly bought if it in any way increases the risk of breakdown, particularly as the cost of switchgear is relatively small compared with that of the mains. One very common error is to save money by proportioning switchgear according to the capacity of the apparatus which it controls; this entirely overlooks the primary duty of switchgear, namely, that of dealing with short-circuits,

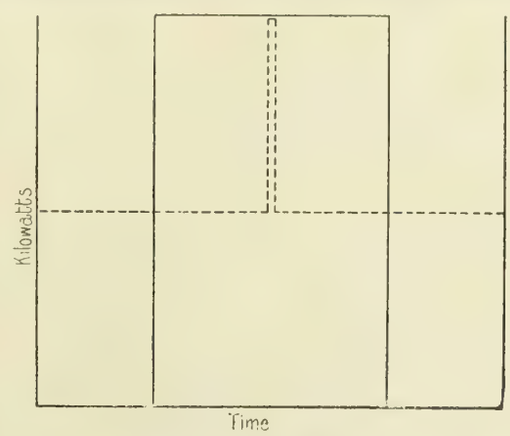


Fig. 3. Extreme Forms of Load Curve for a given number of units at 50 per cent. Load Factor.

the severity of which may be as great on small apparatus as on large.

Faults on switchgear fall into three categories: (1) Faults under short-circuit conditions. (2) Failure of apparatus under normal conditions. (3) Faults due to mistakes in operation.

(1) The means for preventing the failure of switches under short-circuit have already been considered, but if for any reason the switch is unable to operate properly an explosion

* Hunter and Shand, British Patent No. 11586 (1912).

may occur when breaking a short-circuit, and it is therefore desirable to limit the ensuing damage as far as possible by preventing the explosion affecting other panels and by discharging any gases which may be produced in such a way that they do not cause short-circuits either on the damaged panel or on others. Even though a switch should explode it will often still interrupt the circuit, and it should therefore be isolated from other apparatus on the panel and all the leads to it should be insulated in order to prevent them being short-circuited by the

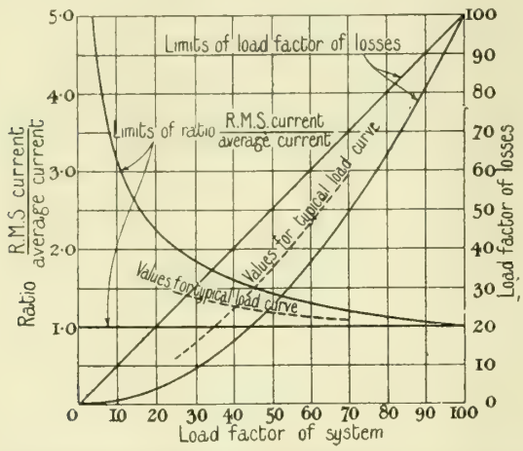


FIG. 4.—EFFECT OF SHAPE OF LOAD CURVE ON R.M.S. CURRENT AND LOAD FACTOR OF LOSSES.

products of the explosion. Other effects of a short-circuit, even on switchgear other than that immediately involved, are the large mechanical forces and the fusing of connections by the heavy currents. The latter effect is more particularly liable to occur in current-transformer primary windings, which should therefore always be of heavy section.

(2) Failure of apparatus under normal conditions may occur owing to such causes as plaster falling on bus-bars, and short-circuits due to mice, rats, &c., but such dangers can be readily guarded against once they are realised. Another fruitful cause of trouble is the potential transformer; these should not only be most carefully constructed, but their number should be strictly limited, and under no circumstances should they be connected to the bus-bars without the intervention of an oil switch.

(3) Mistakes in operation probably account for more switchgear faults than any other cause and they are liable to be made even by the most careful operator, so that so-called "foolproof" arrangements should not be considered as disparaging to the operating staff and undoubtedly justify their slight extra expense, quite apart from the increased safety for operators and other persons who may be working on the switchgear.

The first and most obvious precaution is an interlock between each oil switch and its corresponding isolating switches in order to prevent the isolating switches being either opened or closed unless the oil switch is open, thus preventing any possibility of making or breaking circuit on an isolating switch.

The second precaution is an arrangement to facilitate the routine earthing of feeders, which is responsible for numerous mistakes owing partly to the fact that the person who is carrying out the earthing cannot be at both ends of the feeder at once and has therefore to rely on a second party to see that the feeder is dead from the far end. By using permanent earthing switches it is a simple matter to interlock at the earthing end so as to ensure that the earthing switches cannot be closed until the oil switch is opened, and vice versâ; it is, however, difficult to protect against earthing a feeder which is alive from the far end, and all that can be done is to operate the earthing switches from a safe distance and to make the earth as quickly and definitely as possible.

The third and equally important precaution is to guard all live apparatus either by screens or by making the switchgear ironclad. Although it may sound difficult it is really a simple matter so to interlock the guarding arrangements with the switchgear mechanism that it is quite impossible to obtain access to live conductors or to make any such conductors alive while access can be obtained to them. Briefly, the guarding arrangements should fulfil the following conditions: (*a*) That access cannot be obtained to the feeder ends unless they are earthed. (*b*) That access cannot be obtained to the oil switch unless it is isolated or earthed from both sides. (*c*) That access cannot be obtained to the bus-bars or gear in connection with them unless all the circuits connected to the particular section of bus-bars are isolated.

II. (*a*). **The Economical Section of Mains.**—Although it is generally known that the economical cross-section of a main is that at which the sum of the annual charges and the value of energy lost is a minimum, it is seldom that any practical use is made of the formula. This is partly owing to the difficulty of calculating the losses and of placing the correct value upon them when calculated, and also partly because there is an impression that the resulting cross-section would work out to a figure inconsistent with that required by considerations of carrying-capacity and voltage-drop. In the following investigation an attempt is made to apply the formula to the special case of high-pressure distribution systems, and this seems to show that for this case at any rate the results are commercially useful.

The annual charges which have been taken for underground and overhead mains at various voltages are shown in Fig. 1. These are based on average commercial prices, allowing interest at the rate of 5 per cent. per annum,* and depreciation at 2 per cent. for underground mains and 3 per cent. for overhead mains, suitable allowance being made for trench work in the former case and for wayleave charges in the latter. With compound interest at 5 per cent. the rates allowed for depreciation are sufficient to enable the underground mains to be replaced after 22½ years and the overhead mains after 17½ years, allowing a scrap value of 20 per cent. in each case. It is probable that these figures considerably underestimate the life of mains, but conservative values have been taken so that there may be no question of the importance of capital charges being minimised.† It will be noticed that in the case of overhead mains only one curve is given, as up to 20,000 volts the only difference is in the insulators, and this is so small that it is usually worth while to make the line suitable for 20,000 volts, although it may only be intended to operate it at a lower voltage. Higher voltages than 20,000 will not be considered, as the design and manufacture of apparatus for such higher voltages is not sufficiently standardised to enable definite annual charges to be assumed.

The only losses which are important enough to be taken into account in this investigation are the resistance losses in the copper conductors; and in estimating their value it is necessary, as in all estimates of the cost of producing electricity, to take account of the effect of the addition of the load

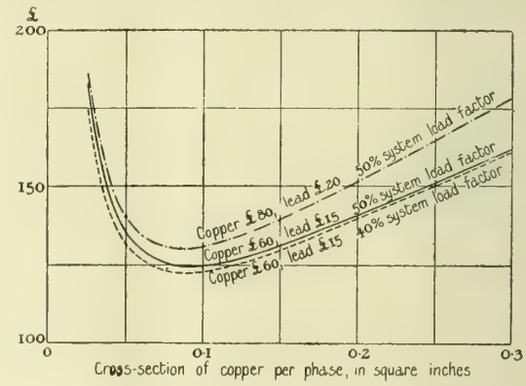


FIG. 5.—COMBINED ANNUAL COST OF INTEREST, DEPRECIATION, AND ENERGY LOSSES PER MILE OF 6,000 VOLT UNDERGROUND MAIN CARRYING A MAXIMUM LOAD OF 100 AMPERES.

considered to the normal load of the system. It is not the load factor of the particular type of load which matters, but its effect on the load factor of the system; in fact a load with quite a poor load factor may be distributed over the day in such a manner that it actually improves the load factor of the system considered as a whole. Unfortunately resistance losses constitute a load which is far from beneficial; not only is there no diversity between the curve of losses and the main load curve, but the peaks of the former are accentuated owing to

* This is assumed to be a reasonable figure for a sound industrial concern operating on a fairly large scale; municipalities and similar bodies would usually be able to obtain their capital at a somewhat less rate of interest.

† No allowance is made for repairs, as these consist almost entirely of jointing and labour, which are independent of the cross-section of the main.

the fact that resistance losses vary as the square of the load. Of course the losses in different parts of the system will have different load factors, depending on the load factors of the currents in the particular parts, but considering them as a whole it is safe to assume that on the average the curve of total losses is proportional to the square of the main load curve.

In order to obtain definite figures as to the value of the energy lost certain fundamental data must be assumed, and accordingly a system has been taken having a maximum load of not less than 50,000 kw. and an average load factor of 50 per cent.; figures which fairly closely correspond to what may be expected if the system deals with the general demand over a reasonably extended area.

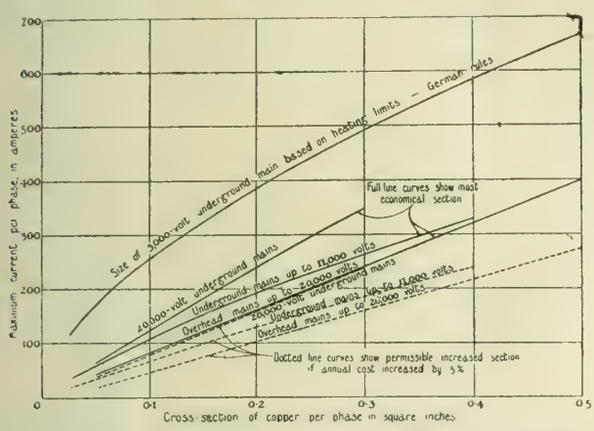


FIG. 6.—MOST ECONOMICAL CROSS SECTIONS OF 3-PHASE MAINS FOR VARIOUS MAXIMUM CURRENTS.

In Fig. 2 the full-line curve shows the assumed load curve of the typical system with a load factor of 50 per cent., and the dotted curve shows to an enlarged scale the shape of the corresponding loss curve, which has a load factor of only 35 per cent. From an analysis of the fixed and running charges the cost per unit of generating these losses at the power stations can be calculated, and to this must be added the fixed charges on the increased capacity of the distribution system necessary to transmit these losses. They do not directly increase the carrying capacity of the distribution system since they are manifested as voltage drop, but this causes the load to be supplied at a lower voltage and thus incidentally increases the current that the distribution system has to carry. Since the power stations can seldom be located at the exact electrical centre of gravity of the load, the losses have to be transmitted, on the average, over say two-thirds of the distribution system and should therefore bear two-thirds of the fixed charges of the latter. There are of course further losses in transmitting the primary losses, but these are quantities of the second order and may be neglected. Taking the cost of the distribution system as two-thirds that of the power stations, the value of resistance losses on the typical system considered is about 0·25d. per unit.

Since the resistance losses over a given time are proportional to the mean square of the current, it is very necessary in calculating them to take account of the shape of the current load-curve. This will be readily seen by considering the two extreme forms of a 50 per cent. load-curve shown in Fig. 3. In the first case the R.M.S. current is equal to the average current, while in the second case it is $\sqrt{2}$ times it for the particular load factor of 50 per cent.; or more generally for any load factor it is $\sqrt{(100 \div \text{load factor})}$ times the average current. The load curves which are met with in practice lie between these extremes, and for the typical 50 per cent. load curve given in Fig. 2 the R.M.S. current is 1·18 times the average current. The full lines in Fig. 4 show the extreme values of this multiplier for different load factors, and the dotted line the approximate values for the usual type of load curve; corresponding extreme and usual values for the load factor of the losses are also indicated.

On the system which we are considering, the load factor of the mains nearest the power stations will not be much less than the system load factor, viz., 50 per cent., but for mains on the outskirts it will be much less, probably as low as 30 per cent. Over the whole network the average would probably be about 40 per cent., and it will be seen from Fig. 4 that the corresponding R.M.S. current would be 1·25 times the average current. Calculating the losses on this basis and taking their value as 0·25d. per unit, the annual value of the losses per mile of 3-phase main is £0·000296 I^2 A, where I is the maximum current in amperes and A is the cross-sectional area of the conductor of each phase in square inches. The value is expressed for convenience in terms of the maximum current, since mains are usually laid to suit a given maximum current.

By adding the curves of annual charges and value of losses for mains of various sizes for any particular maximum current, a curve is obtained of the type shown in Fig. 5, which refers to a 6,000-volt underground cable required to deal with a maximum current of 100 amperes. The most interesting feature of this curve is that the most economical section is not very definite; it is actually 0·09 sq. in., but for 2½ per cent. increase in the total annual costs the section can be increased 44·5 per cent., or decreased 27·2 per cent., the corresponding figures for 5 per cent. increase in annual costs being 65·5 per cent. and 36·1 per cent. respectively. It follows that it is not sound practice to cut the section of mains too fine, more especially since it is a most expensive matter after a main is once laid to increase its carrying capacity if this should prove too small.

In order to see to what extent the results are dependent on the particular system load factor which has been selected, a corresponding curve has been calculated in exactly the same way but assuming a system load factor of only 40 per cent. This is shown dotted in Fig. 5 and gives a reduction of only 2 per cent. in the most economical section, and 2 per cent. in the minimum total annual cost per mile, compared with the original curve. The difference between the two curves is so small because the reduction in the number of units lost at the lower load factor is nearly balanced by the extra value of the losses per unit due to the lower load factor of the losses. A further curve has also been added—shown chain dotted—to show the extent to which the results are affected by the price of copper and lead. The original curve corresponds to basis prices of £60 and £15 per ton respectively, while the chain-dotted curve corresponds to basis prices of £80 and £20 per ton. This shows that the influence of ordinary variations in metal prices is negligible.

By plotting a series of curves similar to the full-line curve in Fig. 5, the curves shown in Fig. 6 have been obtained. The full lines in Fig. 6 give, for underground and overhead mains at various voltages, the most economical cross-section for any given maximum current, while the dotted lines show the

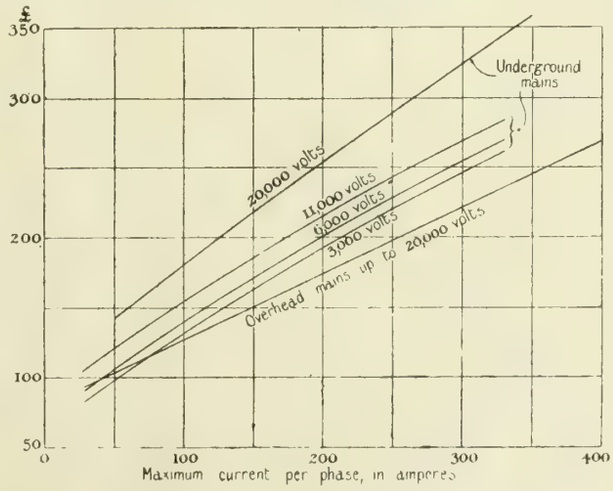


FIG. 7.—MINIMUM TOTAL ANNUAL COST PER MILE OF 3-PHASE MAINS FOR VARIOUS MAXIMUM CURRENTS.

increased cross-section corresponding to 5 per cent. extra annual cost. It will be noticed that up to 11,000 volts in the case of underground mains, and up to 20,000 volts in the case of overhead mains, the voltage makes no difference to the economical cross-section; and from Fig. 1 it will be seen that this is because between those limits the annual charges happen to differ by approximately constant quantities which are independent of the cross-section.

To show how the economical cross-sections compare with sections settled by considerations of the safe carrying-capacity, a further curve has been plotted showing the carrying-capacity of armoured 3-core 3,000-volt cable on the basis of the rules

of the Verband Deutscher Elektrotechniker. As the rules refer to continuous loads, and the maximum load is usually not maintained for a sufficient time to heat up the cable fully, the curve has been plotted on the assumption that the equivalent heating current is the mean between the R.M.S. current and the maximum current, *i.e.*, 0·75 of the maximum current in the present instance with a 40 per cent. feeder load factor. The reduction for voltages up to 11,000 is not more than 10 per cent., but unfortunately no figures are available at present for 20,000-volt cables. It will be seen that except for 20,000-volt cables the economical section gives an overload margin of as much as 100 per cent. in nearly all cases, and even for 20,000-volt cables it is evident that a considerable margin exists, so that it is quite permissible to settle the cross-section of mains on the basis of maximum economy. That it does not pay normally to operate cables at the maximum current density allowed by heating limits is of interest, since it means reduced voltage-drop per mile and consequently an increased radius of distribution for a given voltage.

From the series of curves used in determining the economical sections it is also readily possible to find the minimum annual costs of interest charges, depreciation, and losses per mile of main for given maximum currents, on the assumption that the economical sections which correspond to those currents are used. If an allowance for repairs is added, the resulting figures will give the total minimum annual cost per mile of main, thus providing a definite basis on which the relative economy of alternative arrangements of mains can be determined. The curves in Fig. 7 have been obtained in this manner, the allowance for repairs being taken as a certain percentage of the cost of a 0·15 sq. in. main, since repairs consist almost entirely of jointing and labour and their cost is therefore independent of the cross-section. The percentages which have been taken are 1 per cent. for underground mains and 2 per cent. for overhead mains, but these must only be looked upon as approximations, since the cost of repairs depends on so many conditions.

(*To be continued.*)

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ELECTRICAL, 1915.

Electric motor starters and controllers. Schattner, Travis, and Walton. 10752.
Means for suspending and adjusting electricity overhead conductors. British Insulated and Helsby Cables, Ltd., and Astley. 11172.
Electrical windings. British Thomson Houston Company. 11263.
Lamp-holders for electric lamps. Guth. 11723.
Rectifiers for electric currents. British Thomson-Houston Company. 12666.
Electro-magnetically-operated brake. Lewis. 13679.

1916.

Electric lighting means. Woods, R. S. 288.
Electric motor control systems. Igranic Electric Company. 1643.
Switching apparatus for interconnecting telephone lines by electro mechanically-controlled switches. Aldendorff, F. 4699.

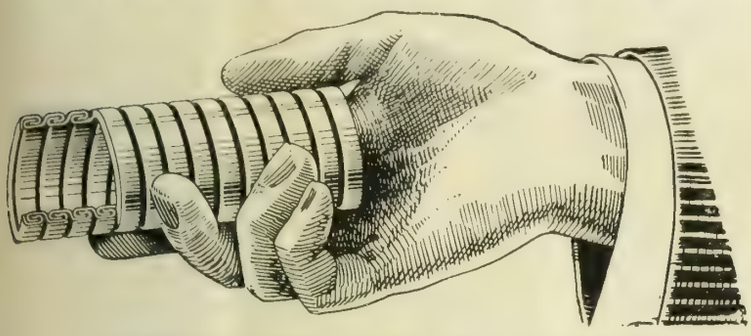
METAL QUOTATIONS.

TUESDAY, AUGUST 8TH.

Aluminium ingot	—	per cwt.
,, wire, according to sizes, &c. .....from	—	,,
,, sheets ,, ,, ... ,,	—	,,
Antimony	£95/–/–	per ton.
Brass, rolled	1/3⅝	per lb.
,, tubes (brazed)	1/4¾	,,
,, ,, (solid drawn)	1/2¾	,,
,, ,, wire	1/2⅞	,,
Copper, Standard	£107/10/–	per ton.
Iron, Cleveland	87/6	,,
,, Scotch	—	,,
Lead, English	£29/15/–	,,
,, Foreign (soft)	£28/15/–	,,
Mica (in original cases), small	6d. to 3/–	per lb.
,, ,, ,, medium	3/6 to 6/–	,,
,, ,, ,, large	7/6 to 14/–	,,
Quicksilver	£17/12/6	per bottle.
Silver	31⅝d.	per oz.
Spelter (American)	£44/–/–	per ton.
Tin, block	£167/5/–	per ton.
Tin plates, I.C.	29/–	per box.
Zinc sheets	£72	per ton.

State of the Skilled Labour Market.—According to the July issue of the "Board of Trade Labour Gazette," the high level of employment of recent months was, on the whole, maintained in June. The war trades were still extremely active; in the others there were slight fluctuations, some showing an improvement and others a decline. The number of workpeople in industry was, of course, much less than a year ago, but those remaining were more fully employed. Employment in June in the coal mining industry continued very good. Iron and shale mines were well employed, but in tin mines employment was still quiet. In the quarrying industry employment was fairly good on the whole. The pig iron industry still suffered from shortages of labour and raw material, but employment continued good; at iron and steel works it was very good. Great activity prevailed in the engineering and shipbuilding trades, and much overtime was worked. There was a further reduction in the number of tinplate and steel sheet mills in operation, but most of the other metal trades continued very active, and much overtime was worked.

FLEXIBLE METALLIC TUBING



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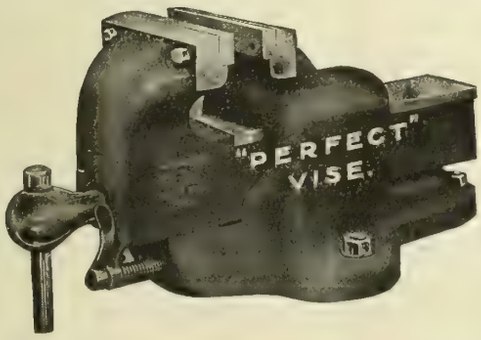

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By JOHN S. G. PRIMROSE, A.R.T.C., A.I.M.M., M.I.M.

Lecturer on Metallurgy, and demonstrator on Metallography at the Royal Technical College, Glasgow.

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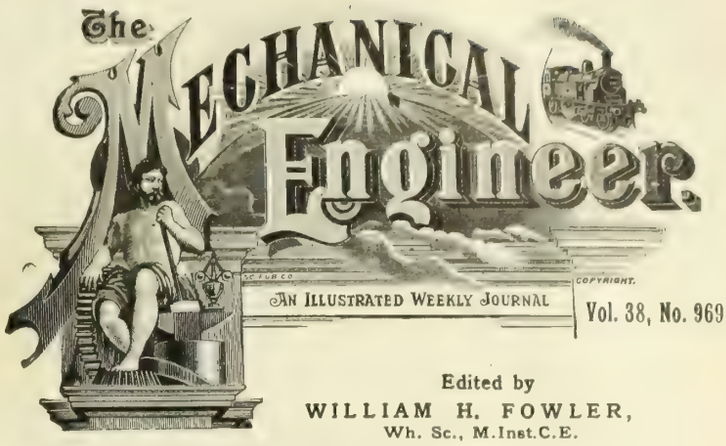

Edited by
WILLIAM H. FOWLER,
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Fusible Plugs.

The advantages and disadvantages of the fusible plug in locomotive boilers was the subject of a report of a committee and subsequent discussion at a recent meeting of the American Master Boiler Makers' Association, from which it appears that the device has met with a large amount of disfavour in the States, and is now to a great extent being dispensed with. According to the committee, this attitude is due (1) to the location of these plugs, which is generally between the first and second row of crown bars at the forward end of the firebox; where, owing to the extreme heat, the plug often burns out and requires renewal; (2) to the overheating of the brass part of the plug, owing to excessive thickness, which often results in the fusible metal being melted without low water; (3) to variation in temperature of the plug, and the crown sheet surrounding it rendering it difficult to maintain tightness without resorting to a caulking tool or renewing the plug entirely, a procedure which the committee state they deem necessary once a week, and which, they add, "rapidly enlarges the hole in the crown sheet and makes it necessary to apply a patch or bush the hole"; (4) to trouble involved by the frequent lowering and raising of the water level each time the plug is renewed, and the filling up with cold water which is often necessary, with its damaging effect to the smoke flues and firebox sheets. It seems curious that this fitting, the usefulness of which is almost universally recognised by engineers in this country, should have a tarnished reputation in the States, and we cannot help thinking that the difference of opinion is due to the cruder designs of plug there used. In this country the fitting has received a great deal of attention, especially during the last quarter of a century, owing to the steady increase of temperature, due to rise in pressure and the effect this exerts when long continued on fusible alloys. Patient investi-

gation, however, has enabled the difficulties on this score to be surmounted, and though the conditions of a locomotive in respect to temperature are extreme as compared with other types, and, generally speaking, more severe in this country than in the States, it is unusual for locomotive boilers not to be equipped with this fitting, and we are not aware that troubles such as apparently attend its use in the States are met with here. The necessity for cleanliness is, of course, realised, for the accumulation of even a thin coating of scale is sufficient to render a fusible plug useless. It is equally recognised also that a fusible alloy cannot be depended upon for an indefinite period. With a well-designed plug, however, the renewal of the fusible alloy once every 12 months is sufficient, or, in extreme cases, say half that period. It will, we think, be news to most British locomotive engineers that, in order to maintain tightness, it is necessary to remove the plug seating once a week, and it is difficult to avoid the conclusion that this procedure, if it is imperative, is due to defective design, and that locomotive engineers in the States might benefit by a study of the types that are used here. The question of the best alloy to use depends on circumstances, and makers naturally keep information of this kind to themselves, though there is no special secrecy about them, and mixtures of lead and tin can be formed having melting points as high as 600° Fah. or as low as 360° Fah. Some little time ago the question of fusible plugs was made the subject of investigation by the U.S. Bureau of Standards owing to disastrous explosions occurring through plugs failing to act. A large number of plugs were collected from a variety of sources, which had been in service from four to 12 months, and analysis showed that the majority of these consisted in the main of tin, the percentage varying from 96 to 99 per cent., and that the remaining 4 per cent. was composed of zinc and lead in varying quantities. The Bureau stated that in many of these plugs an interlocking network of oxide developed throughout the tin after a period of service, and formed a solid, hard mass on the fire side, which greatly raised the melting point; in some cases beyond that of gunmetal or even of boiler plates, and it is easy to understand that with the gradual building up of such a constituent the behaviour of plugs may be erratic. The fact that stood out most prominently in this investigation was that zinc is the objectionable constituent, and that for the manufacture of alloys in fusible plugs the tin should be as pure as possible, and that in no case should the amount of lead or zinc impurity be permitted to exceed one-tenth of 1 per cent.

BOARD OF TRADE DEPARTMENTAL COMMITTEE ON THE IRON AND STEEL INDUSTRIES.

THE Departmental Committee consists of Mr. G. Scoby Smith, chairman, Sir Hugh Bell, Bart., Mr. Archibald Colville, Mr. John Hodge, M.P., Mr. James Gavin, Mr. George Mure Ritchie, Mr. Henry Summers, Mr. Benjamin Talbot, Mr. John King, Mr. John E. Davison, and was appointed "to consider the position of the Iron and Steel Industries after the War, especially in relation to International Competition, and to report what measures, if any, are necessary or desirable in order to safeguard that position." In order to carry out its investigations, the Committee desires to elicit exact and detailed information from a number of representative and individual firms, and from industrial, commercial, and labour organisations, with respect to: (1) The extent and area of trade, and capital normally employed. (2) The dependency upon resources external to this country for supplies of material and plant. (3) Labour relations, labour restrictions (if any), and comparative conditions in the industry. (4) British methods of conducting foreign business contrasted with foreign methods of conducting export business. (5) The effects of manufacturing and commercial co-operation upon trade at home and abroad. (6) The extent to which British industry is adversely affected whether as regards (*a*) the retention of business hitherto or previously secured, or (*b*) its capacity for expansion by the existence of foreign tariffs, preferential arrangements, bounties, subsidies, or special facilities granted by foreign governments, railways, or trade combinations, to their manufacturers or exporters; and what, in your opinion, is the remedy. (7) Terms of payment and of credit. (8) Technical education, skill, and nature of employés. (9) The effect, if any, of wayleaves, and mining or other royalties upon the industry, either as regards home or export trade. (10) The effect, if any, of railway and shipping rates upon the industry, as regards home, or export trade. (11) General information. The recommendations of the Committee must depend for their effectiveness upon the co-operation of all who are interested in the British iron and steel industries. The Committee, therefore, invites the active support and assistance not only of individuals, but also of industrial organisations of whatever character. The Committee suggests that the various trade organisations should submit either through their secretaries or through small committees, a general statement of their views together with suggestions which in their opinions might desirably form the foundation of practical measures in the future. The general evidence might suitably be supported by the presence of a deputation representative of the organisation as a whole. The Committee will be glad to receive statements supported by verbal evidence from representative firms, and from individuals, whose depositions, in the opinion of the Committee, will be valuable to their work. It will also welcome the assistance of import and export merchants who are interested in the handling of the products of the iron and steel industries at home and abroad.

LOSSES IN CABLES AT HIGH FREQUENCIES.

THE results of some tests to determine if there is any appreciable difference in the losses in cables which depends upon the arrangement, the size, and the insulation of the individual strands which make up a cable, and to determine what combinations of these various features will give a cable best suited for use at high frequencies under specified conditions, are given in a paper by E. F. Northrup and R. G. Thompson recently presented before the Franklin Institute. The following are the conclusions drawn from the tests:—

In a cable the strands of which are parallel the loss is appreciably greater than it is in a solid wire having the same cross-section; and, surprising as it may appear, if this same cable is very much twisted, so that the wires lie in concentric spirals, the loss decreases 50 per cent. or more and becomes less than in a solid wire. The tests appear to show that the more the cable is twisted the greater is the reduction in the loss.

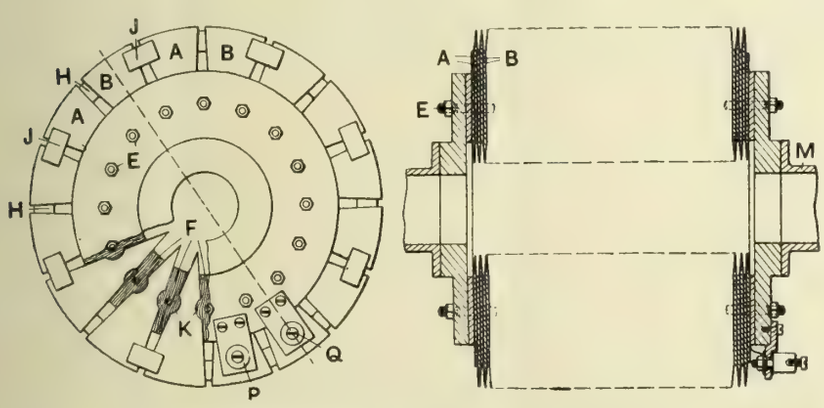
With the exception of the case just mentioned, the alternating-current resistance of a cable is less than that of a solid wire of the same cross-section. The smaller the individual wires and the better they are stranded or braided and the more perfectly they are insulated from each other, the more nearly does the alternating-current resistance approach the direct-current resistance for a given cable. It is, further, important that individual wires should be stranded or braided so that in passing along the cable an outside wire becomes an inside wire, and then again vice versâ.

Well-insulated cable strands are obtained by using enamelled wire, though good insulation may be partially obtained by thoroughly treating the cable with an insulating varnish. Our tests seemed to indicate that the decrease in loss obtained by using enamel-insulated wire in cables would hardly warrant the extra cost of this kind of insulation, particularly in cases where only a portion of the total current which flows is high-frequency current. A case of this character is where the secondary of a high-tension transformer feeds an oscillating circuit, some of the high-frequency oscillating current finding its way into the secondary winding of the transformer.

SILENCING THE EXHAUST AND UTILISING THE WASTE HEAT OF INTERNAL-COMBUSTION ENGINES.

A PATENT recently granted to Mr. F. W. Rixon, 93, Cromwell Road, Bishopston, Bristol, relates to silencers for internal-combustion engines of the kind in which thermopiles are employed for the conservation of energy which would otherwise be dissipated as waste heat. Whilst more especially designed for use on the engines of vehicles driven by internal-combustion engines, it is also applicable to gas and similar engines. The products of combustion of such engines are generally of comparatively high temperature when they enter the exhaust pipe, and the more particular object of the invention is to convert the heat energy into electrical energy which would be available for the charging of accumulators and used for the purposes of ignition, lighting, and so on.

Referring to the illustrations, the cylindrical wall of the silencer is composed of a plurality of substantially triangular thermopile couples A, B, lying in transverse planes and arranged in longitudinal series between circular end plates, held together by bolts E disposed between adjacent series of couples, the series of couples being spaced apart angularly by insulating medium F. Each couple is constituted by a pair of substantially triangular plates A, B of different metals or metallic alloys, the plates A of one metal in a series alternating with the plates B of the other metal, and the apices of the plates are bent towards, and are united to, one another by welding, and are directed towards the axis of the silencer, whilst their bases are bent away from one another and similarly united to the bases of the adjacent plates B and A respectively of the couples on either side thereof in the series. The plates in each series are separated from one another by thin sheets of asbestos, paper, or other suitable insulating medium, and the couples are so arranged in the series that one series has at the left-hand end a plate A and at the right-hand end a plate B, whilst the next series has at the left-hand end a plate B and at the right-hand end a plate A, and so on around the series, and the plate A at the left-hand end of one series is connected with the plate B at the same end of one of the adjacent series by a copper strip H, whilst the plate B at the right-hand end of the series is connected with the plate A at the same end of the other of the adjacent series by a copper strip J, and so on around the series, so that the strips H and J are staggered angularly.



SILENCER AND WASTE HEAT UTILISER FOR INTERNAL-COMBUSTION ENGINES.

The edges of the plates A, B are cut away at K to accommodate sufficient insulating medium between the edges and the bolts E, and the insulating medium does not extend towards the axis of the silencer to so great an extent as the couples A, B, so that on the one hand the inner junctions of the couples are exposed to the heat of the exhaust gases and on the other hand an enlarged space is provided for the expansion of the gases, the diameter to the bottoms of the longitudinal grooves formed between adjacent series of couples being greater than that of the exhaust pipe M. The series of couples are insulated from the end plates by rings of asbestos, and the plates A, B at the same end of two adjacent series, instead of being connected together by a copper strip J, are electrically connected with terminals P, Q respectively, which are carried in insulating bushes by lugs secured to the end plate. The insulating medium F does not extend to the outer ends of the couples and consequently longitudinal grooves are left between adjacent series so that in use the inner ends of the couples are submitted to the heat of the exhaust gases whilst the outer ends thereof are cooled by the ambient atmosphere. The plates A and B are made of iron and copper nickel alloy respectively, and the series of couples may be connected in series or in parallel so as to ensure the generation of current of the required value for effecting ignition of the explosive charges in the engine cylinders, lighting of lamps, and charging of accumulators.

THE MANUFACTURE OF ELECTRIC CABLES.

THE Society of Engineers is, we are informed, experiencing considerable difficulty this year in arranging its usual visits to engineering works during the summer. Recently, however, Messrs. Johnson & Phillips were able to show them a portion of their works at Charlton, including a large plant for the manufacture of telephone cables capable of dealing with cables up to 1,000 pairs of small wires for local lines, and also "trunk" cables consisting of fewer but heavier wires. One shop contained a large number of multiple-headed machines for covering the single wires with one or two layers of paper put on longitudinally or spirally, and forming a more or less loose tube of paper, also a number of special high-speed twinning machines which are used to twist two of the covered conductors together, forming the "twin," which is wound on to a larger bobbin. These bobbins are taken to the "laying-up" machines—in another shop. Several of the "laying-up" machines are arranged for laying-up pair telephone cables, of which large quantities are made.

Other larger machines, consisting of three or four sections, each carrying different numbers of bobbins, are designed to "lay-up" the twinned conductors into cables, each layer of conductors being stranded in opposite directions. These machines will deal with cables up to 150 pairs. If the cable has to be made up with a larger number of pairs, it then goes to a still larger machine having four or five sections, the largest of which carries 70 standard bobbins, or if necessary, 100 or more narrower bobbins. The cable can be built up in this machine with several more layers of conductors put on in opposite directions, until it reaches a total of 800 to 1,000 pairs, according to requirements. The cable so made is coiled on to steel drums, which are then placed in large steam-heated hermetically-sealed chambers to dry the paper covering, the moisture being carried off by means of an air pump which causes a more or less perfect vacuum in the chamber.

When the cable is thoroughly dried it is taken to the lead-covering press and coated with lead. These presses consist of a lead container having a point or core and die through which the cable to be covered passes. Two hydraulic rams are arranged to work into the lead container and operated on the lead. Above the container is the lead-melting pot, the molten lead being run from the pot into the container, where it is allowed a few minutes to "set" and then the hydraulic pressure is applied. The point or core through which the cable passes is cone-shaped, so that when the pressure is applied the lead moves forward off the core and through the die, this being the only exit, and the point of the core being close to the die a tube of lead is formed of such size as to cover the cable, take a grip of it, and pull it through the press as the pipe is formed. The cable so covered is coiled on to drums and tested under water—with the ends of the pipe and cable projecting—to see that the pipe is quite sound and watertight. These lead-covering presses can deal with cables of any practical length without any joint in the lead pipe, because when a charge has as far as practicable been extruded the hydraulic ram is withdrawn and a further charge of molten lead is run into the container and automatically burns itself on to the block of lead which is left in the chamber and around the cable.

In the same department there were a number of stranding machines of various sizes for dealing with copper strands com-

posed of different sizes and numbers of wires as used for cables for power transmission and lighting, also a number of paper-insulating machines for covering the strands with varying numbers of layers of paper according to the thickness of insulation required. These machines each have four or five heads, each head having three arms, and each arm adapted to carry three discs of paper, enabling the machines to put on 36 to 45 layers of paper at one operation. The heads of these machines have hollow mandrels through which the cable passes, while the head revolves laying the strips of paper on the cable spirally. From these machines the cable is coiled into steam-heated hermetically-sealed pans, all moisture being evaporated and drawn off by means of an air pump. A resinous compound is admitted into the pan while it is still under vacuum, and the dry paper readily takes up the compound, and in a short time becomes thoroughly saturated. When this condition is reached the vacuum is broken, the pan opened, and the cable is passed through the lead-covering press, as before described in connection with the telephone cables.

After lead covering, the power and lighting cables are usually armoured with steel wires or steel tapes, and protected with preservative tapes or jute yarns and compounds. The wire-armouring machine is practically the same as the large stranding machine, arranged to carry a large number of bobbins, it sometimes being necessary to use as many as 100 or more wires. The steel-taping machine has a very massive head provided with two worm-adjusted quadrants, each of which carries a disc of steel tape. The head has a hollow mandrel through which the cable passes, and the head revolving lays the tapes on the cable helically. Each tape is laid on in an "open" helix, the tapes being adjusted so that the outer one covers the space between the coils of the inner tape so as to provide a perfect shield. Over the steel tapes it is usual to put one or two tapes or layers of jute and compound, and this is done at the same time as the armouring.

In the rubber cable department were seen wires and cables of various sizes being covered with pure and compounded rubbers, afterwards vulcanised and protected by tapes, braiding, &c. Especially interesting were the longitudinal rubber-covering machines, which are arranged to cover 12 conductors simultaneously with two, three, or four layers of rubber. In these machines the wires are made to pass side by side through grooved rollers, while strips of rubber are fed in with the wires—one above and one below the rollers, crushing the rubber strip together between the wires and practically forming a band of 12 covered wires with a fine fin of rubber between them. The crushing of the rubber has the effect of uniting the two strips of rubber at the side of each wire, and the fin is so thin that the band easily splits up, leaving 12 separate covered wires, which are coiled on to separate drums. These rubber-covered conductors are then wound on to steel cylinders and placed in steam-heated pans in which they are submitted to a certain temperature for a certain period, according to the size of the wire or cable and to the quality of the rubber being dealt with. After this operation the cable is protected with tapes or braiding and preservative compound according to specification.

For making the smaller strands Messrs. Johnson and Phillips have installed many of their latest high-speed stranding machines, which run at speeds of 1,250 to 1,000 revs. per minute. These are comparatively long machines, with bobbin carriages arranged in a long cage, tandem to one another, and supported in ball bearings in such a manner that they remain stationary while the cage revolves around them. The cages are splendidly balanced and they are supported at intervals in their length on special rollers which ensure very quiet running. In addition to the stranding and covering machines there were also various machines for cutting the rolls of rubber and cloth into strips to suit the various sizes of conductors. The majority of the rubber-covered cables when completed are tested under water, and the visitors saw several large testing tanks and special testing rooms engaged upon this work. Practically all the machines used by Messrs. Johnson & Phillips in their cable-making department are of their own manufacture, this work being a speciality of theirs. Owing to the short time at the disposal of the members, they were unable to go through various other shops engaged in the manufacture of transformers, switchboards, and switchgear, instruments, arc lamps, &c., but a short time was spent in the general engineering shop.

EQUALISATION OF LONG LOCOMOTIVES.*

THE first American-built locomotive of which we have record appears to be the small experimental engine constructed by Peter Cooper, and used on the Baltimore and Ohio Railroad from Baltimore to Ellicotts Mills, August 28th, 1830. This embodied a rigid frame, upright boiler, and a single $3\frac{1}{4}$in. by $14\frac{1}{4}$in. vertical cylinder connected to one axle through a cross shaft and gearing. The four 30in. wheels of the engine had no springs and were not equalised. On January 4th, 1831, the B. and O. advertised a competition to be held June 1st, and offered to pay $4,000 for the best engine and $3,500 for the next best, which should meet the conditions of tractive power and speed and weigh not more than $3\frac{1}{2}$ tons. Several builders offered engines for trial, but only one met the requirements, and this only after some modification. It was built by Davis & Gartner, of York, Pennsylvania, and consisted of an upright boiler supported on a rigid frame, carried by four wheels 30in. diam., having outside crank axles and trussed side rods, to the centre of which was attached a main rod on each side operated by vertical cylinders fastened to the side of the boiler. It is stated that the engine worked badly in consequence of the action of the springs, due to inequalities of the track and the alternating vertical movement of the pistons. Here were springs but still no equalisers.

In 1828, Horatio Allen had gone to England with authority to purchase three locomotives for the Delaware and Hudson Company, which in 1827 had commenced the construction of a 16-mile railroad between Honesdale and Carbondale, Pennsylvania. This road was opened in 1829, at first using horses; and on August 9th of that year the first locomotive to operate in this country was tried on that line. It was named the "Stourbridge Lion," and was built by the

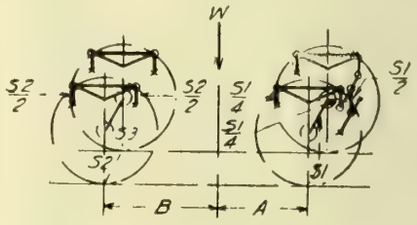


FIG 1

Stephensons, who were at that time the foremost locomotive builders of the world.

In 1830, the South Carolina Railway Company had a locomotive built at the West Point Foundry, named the "Best Friend," and in 1831 another engine, named "The South Carolina," was delivered by the same builders, and was the result of a design prepared by Mr. Allen after his visit of investigation to England. It consisted of a double-ended boiler carried by two pivoted trucks, each containing one pair of small wheels and one pair of larger driving wheels. Here were swivelling trucks, and the first Mallet, a 2—2—2—2. The arrangement of the pivoted trucks under "The South Carolina" seems to be the first effort to provide equalisation, and this scheme was suggested by Mr. Allen in a report to the South Carolina Canal and Railroad Company, dated May 16th, 1831.

In the latter part of this year John B. Jervis, a prominent civil engineer, invented what he called "a new plan of frame, with a bearing carriage for a locomotive engine," for the use of the Mohawk and Hudson Railroad. In a letter published in the "American Railroad Journal," July 27th, 1833, he described the objects aimed at in the use of the truck as follows: "The leading objects I have in view, in the general arrangement of the plan of the engine, did not contemplate any improvement in the power over those heretofore constructed by Stephenson & Co., but to make an engine that would be better adapted to railroads of less strength than are common in England; that would travel with more ease to itself and to the rail on curved roads; that would be less affected by inequalities of the rail, than is obtained by the arrangement in the most approved engines." This device

* Report of a committee presented at the annual convention of the American Railway Master Mechanics' Association, June 20th, 1916.

was never patented and the 4—2—0 with a pivoted truck was entirely satisfactory for those early days. The effectiveness of this arrangement in accomplishing what Mr. Jervis intended was at once recognised, and its almost general adoption on American locomotives followed.

The early Norris and Baldwin engines, each of which firms began the construction of locomotives in Philadelphia in 1832, adopted this wheel arrangement, the Norris engines having the driving axle placed in front of the firebox of the horizontal boiler, and the Baldwin engines behind it. Thus early was the arrangement corresponding to the 3-legged stool adopted, and the success of locomotives on the poorly constructed railroads of this country must be credited to the arrangement devised by Mr. Jervis, who was, perhaps, influenced by Mr. Allen's plan of "The South Carolina." In 1834, Ross Winans patented the application of the principle to passenger and other cars, and a number of suits were brought against various railroads for infringement, but the matter was finally decided against Winans by the United States supreme court.

As the demand for increased power became more insistent, a further improvement in the wheel arrangement was patented by Henry R. Campbell, February 5th, 1836, who devised the 4—4—0 type, and secured broad claims, as follows: "What I claim as my own invention, and not previously known in the above described machine, is the combination and application to each locomotive steam engine of two pairs of driving or propelling wheels and two pairs of guide wheels, and also as a modification and part of my improvement, I claim the combination and application to each locomotive steam engine of two pairs of driving wheels and one pair of guide wheels for the purposes hereinbefore described." This departure from the 3-legged stool principle was not wholly satisfactory in operation, although the driving boxes were carried in pedestal jaws, and the weight of the back end of the locomotive was supported on four springs, one over each box, the springs being the standard semi-elliptic type in use at the present time, and the spring hangers secured to the frame under each end.

In order to overcome the inability of the engine to accommodate itself to the inequalities of the track the next step forward was the invention of the "vibrating beam," by Joseph Harrison, jun., of Philadelphia, patented April 24th, 1838. This patent embodies the first use of the equaliser, and various methods are shown for distributing the load from the frame to the driving boxes, so that, as Mr. Harrison states, "The two wheels on each side may readily adapt themselves to the inequalities of the road without alternating their relationship to the action of the spring." We thus see that in less than 10 years after the introduction of the first locomotive into this country, all the principal elements for the satisfactory equalisation of the machine to run successfully on our cheaply constructed tracks had been developed. The 3-legged stool principle, the weight carried on springs, the equaliser, and the 4-wheel pivoted guiding truck are all shown in the "Mercury," sister engine of the "Atlas," turned out in September, 1839. The American type, or 4—4—0, was a logical development, and it came to stay. Progress did not stop at this point, however, and shortly after a third pair of driving wheels was added, and the patent dated August 25th, 1842, issued to M. W. Baldwin, shows a "flexible beam truck," which was used under large numbers of engines built by the Baldwin Locomotive Works for many years after. The next step was the addition of still another pair of driving wheels, and a patent covering this innovation was issued to Ross Winans, June 28th, 1843. In the meantime, it may be noted in passing, the variable exhaust nozzle had been patented in 1840; the Walschaert valve gear was invented in 1844, the feed-water heater in 1849, and the superheater in 1850.

Having thus briefly traced the early development of the locomotive in this country, the methods followed in working out the actual equalisation of the various classes of locomotive in common use may now be noted. The simplest form of wheel base is the 0—4—0, or 4-wheeled switcher. In order to allow the wheels to follow the irregularities in the track without materially changing the loads on the journals, it is necessary to adopt the 3-legged stool principle. It is well known that a stool having three legs will stand firmly no matter how uneven the ground on which it rests, while one having four legs will rock about and bear unevenly if there is the slightest irregularity from a true plane surface.

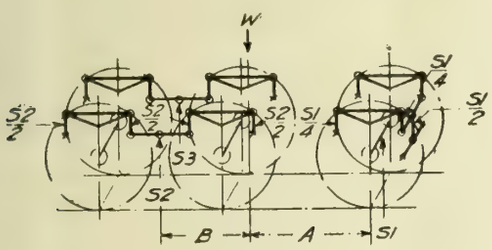


FIG. 2.

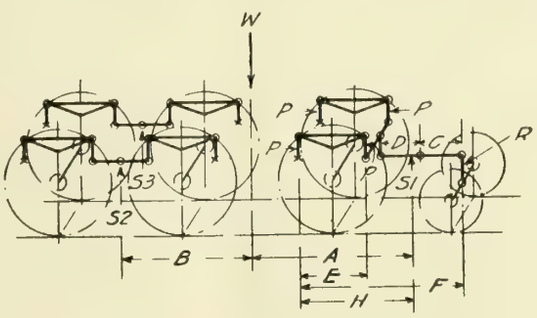


FIG. 4.

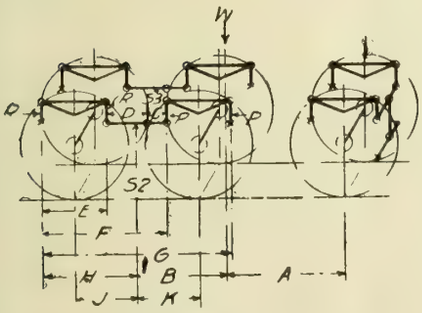


FIG 3

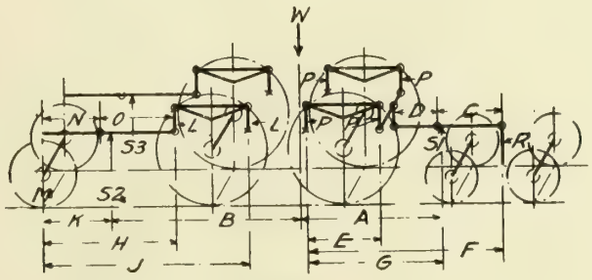


FIG 5.

This involves designing the spring rigging so that the engine frames and all parts attached to them shall be carried on the fundamental points of support, commonly called the 3-point suspension. Both ends of the rear driving springs are anchored directly to the frames, and these springs, having equal arms and resting on the driving boxes, deliver the load they carry directly to the journals of the back axle and thus constitute two of the three legs of the stool. The front springs have their rear ends anchored to the frames and their front ends connected to a cross equaliser, the centre of which is attached to a frame brace as shown in Fig. 1. If the weight of the spring-borne parts of the engine be denoted by W, and the distance of the centre of gravity of this mass from the front axle be A, and from the rear axle B, then the weight carried by the front axle will be $\frac{W\,B}{A+B}$, and the weight carried by the back axle will be what is left over after subtracting the

weight on the front axle from the entire load, or $W - \frac{WB}{A+B}$. Since the front springs are provided with a cross equaliser, these springs form a unit support S_1, located midway between the springs and on the centre line of the axle, thus constituting the third leg of the stool. The load carried is $S_1 = \frac{WB}{A+B}$. The rear springs are independent of each other, not being provided with a cross equaliser, and form the unit supports S_2 and S_3, the load carried by each being $\frac{1}{2}\left(W - \frac{WB}{A+B}\right)$.

On a locomotive of the 0—6—0 type, having six driving wheels and no truck, the back ends of the front driving springs are anchored directly to the frames, while a cross equaliser is provided between the front ends of the same springs. This forms a unit support S_1, which is located midway between the frames and on the centre line of the front axle. The front ends of the second springs and the rear ends of the rear springs on each side of the locomotive are anchored to the frames, while the other ends of the springs are connected to each other through longitudinal equalisers. Usually these longitudinal equalisers are equal-armed, in which case the unit supports S_2 and S_3 come directly at the centre of the equalisers. Assuming that the centre of gravity of the spring-borne weights W comes at a distance A from the front axle and B from the centre of the longitudinal equalisers, the weight carried by the front axle will be $\frac{WB}{A+B} = S_1$ while the weight carried by the other two pairs of wheels will be $W - \frac{WB}{A+B} = S_2 + S_3$. In case longitudinal equalisers are not equal-armed, as is indicated in Fig. 3, the unit supports S_2 and S_3 are located as follows: Keeping in mind that $R = P\frac{C}{D}$, take moments about the rear end of the spring

$$\frac{E \cdot P\frac{C}{D} + F \times P + G \times P}{2\left(P\frac{C}{D} + P\right)} = H,$$

which locates S_2 and S_3. Assuming the centre of gravity of the spring-borne parts W located back of front axle at a distance A, then the weight carried by the front axle is $\frac{WB}{A+B}$, while the weight carried by the rear axles is $W - \frac{WB}{A+B}$, the weight carried by the second axle being $\frac{J\left(W - \frac{WB}{A+B}\right)}{J+K}$ and by the rear axle $W - \frac{WB}{A+B} - \frac{J\left(W - \frac{WB}{A+B}\right)}{J+K}$.

Eight and ten driving wheel locomotives with no trucks are handled in the same way as the above, the designer taking care to anchor the spring hangers to the frames between the drivers, between which the centre of gravity of the spring-borne parts comes. If this point is overlooked there will be danger of some of the wheels not carrying enough weight in case the springs or spring hangers are not properly made, and a derailment may occur.

Fig. 4 represents a Mogul or 2—6—0 type locomotive. The spring hangers in this type of locomotive should be anchored to the frame between the first and second drivers and at the rear of the third drivers, as the centre of gravity of the spring-borne parts comes between the first and second drivers. Referring to the front system of the equalisation and remembering that $R = 2P\frac{D}{C}$, the location of the front support may be found thus:—

$$\frac{E \times 2P + F \times 2P\frac{D}{C}}{4P + 2P\frac{D}{C}} = H.$$

From this the distance A from the front unit support S_1 to the centre of gravity of the spring-borne parts can be found. Generally the arms of the levers between the second and third pairs of drivers are equal, so that the rear unit supports S_2 and S_3 are located half-way between the second and third driving axles and at a distance B from the centre of gravity of the spring-borne weight W, and the weight carried by each pair of wheels can be readily found.

Locomotives of the consolidation, or 2—8—0, type and decapod, or 2—10—0 type, are handled in a similar way, the front system of equalisation consisting of the truck and one or two pairs of driving wheels, depending on the location of the centre of gravity of the spring-borne parts.

In locomotives of the American, or 4—4—0, type, no cross equaliser is used, the centre plate of the engine truck forming the front unit support S_1, while the centre of the equalisers on each side of the locomotive between the drivers form the rear unit supports S_2 and S_3. This form of equalisation is very simple and gives very little trouble. With the addition of another pair of drivers, forming the 4—6—0 type, a trailer truck, forming the 4—4—2 type, or a third pair of drivers with a trailer truck, forming the 4—6—2 type, the equalisation becomes more complicated, and unless it is properly designed trouble may be expected. In all of these types of locomotives, as well as any other type, the equalisation systems should be divided as near as possible to the centre of gravity of the spring-borne parts, as, if this is not done, there is danger of engine truck not carrying its legitimate load, which may result in a derailment. In Fig. 5 is indicated the spring rigging for an Atlantic (4—4—2) type locomotive, the method of determining the weight distribution being as follows:—

Referring to the front system of the equalisation, P represents the load on each of the spring hangers of the springs over the front driving wheels, while $R = \frac{2PD}{C}$ represents the load applied to the front engine truck centre plate. Taking moments about the rear ends of the front driving springs we have $\frac{E \times 2P + F \times \frac{2PD}{C}}{4P + \frac{2PD}{C}} = G$, which gives location of front unit support S_1. This point may fall on, in front of or back of the fulcrum point.

In the rear system of the equalisation, L represents the load carried by each of the spring hangers of the springs over the main drivers and $M = \frac{OL}{N}$ represents the load applied to each trailer truck box. Taking moments about the centre of the trailer axle we have $\frac{H \times L + JL}{\frac{OL}{N} + 2L} = K$, which locates the rear unit supports S_2 and S_3.

Having found the location of the three points of support, S_1, S_2, and S_3, then distances A and B from the centre of gravity of the spring-borne weight W can be found. Then the weight carried at the front support $S_1 = \frac{WB}{A+B}$, this weight being equal to $4P + R = 4P + \frac{2PD}{C}$, from which the amount of load carried by each axle can easily be found. The supports S_2 and S_3 together carry the load $W - \frac{WB}{A+B}$, the load carried by each axle being found as indicated above.

Following the general principles laid down, the weight distribution of any properly designed locomotive can be accurately determined There are, however, locomotives in service in this country in which the spring rigging has not been properly designed, and these locomotives require constant attention to see that the different axles carry the proper weight. In some cases the driving springs are so large and stiff that the engine truck may be entirely removed without making any practical difference in the height of the coupler. Under condition of worn wheels, axles, &c., or improper spring hangers the truck may not carry sufficient weight for safe operation.

CORROSION AND SCALE PREVENTION IN STEAM BOILERS.*

BY ALLEN H. BABCOCK.

There will be described in detail a radical departure from the conventional methods of handling boiler troubles due to corrosion. At present the method considered most highly scientific is to send samples of water to a chemist in order that a proper corrective may be prescribed. The composition of the corrective is usually a trade secret, jealously guarded, which the purchaser uses blindfold. On the other hand, the method to be described applies one corrective to all waters. A different composition of feed water demands not so much a different composition of corrective as a different quantity thereof. A simple chemical test, made by the engineer of the plant, or his clerk, gives the condition of the water in the boiler, under steaming conditions, and determines the quantity of chemicals to be applied. The purchaser now works with his eyes open.

It seems from all that can be ascertained at the present time, that at least there is a method of handling boilers, with a compound applicable to any water under any conditions of steaming, without a material change in the formula. The only requirement is that the boilers must be treated individually; it is not enough to treat a battery, or to treat the feed water going into the boilers in general. The first application by the author of this method was made at the Fruitvale power station of the Southern Pacific Company, the boiler equipment of which consists of 12 water-tube boilers, each of 645 boiler horse-power. It has since been used by the Southern Pacific Company in stationary plants in the oil fields and on locomotives in the same district.

The method is in no respect original with the author. It has been his good fortune to be able to apply the work of another who was similarly situated, but who solved the problem for himself. The results have been such that it seems worth while putting them on record, particularly since a description of the method has lain in the technical literature of this country unnoticed for about three years. Apparently it has attracted almost no attention outside of a very limited circle.

The first inspection of the boilers of the Fruitvale plant after it was put in operation showed that serious corrosion began a very short time after the plant was started, although the boilers were not on regular load. The ordinary remedial measures produced no results at all. Bearing in mind that the plant was put in service to haul trains in the fall of 1911, it is significant that by June, 1912, the feed elements of the boilers were all in serious condition. With a total of 3,360 tubes in all boilers, 252 tubes were requisitioned for replacement during practically the first eight months of operation. By the end of July, 1912, the trouble was extending to the second row of tubes, and 250 more tubes were requisitioned to take care of the trouble. In September, inspection showed that the drums were being attacked. In October, boilers Nos. 1 and 3, after having been equipped with new tubes and placed in service in August, and worked entirely with water treated by the lime process, were found to be pitted worse than ever, and this was after the first serious effort to treat the water had been put into effect. In November, 1912, the piping was modified according to a plan sent by the manufacturers of the boiler, but in December of that year the inspection showed the pitting to be very severe, and in January, 1913, 300 more tubes were requisitioned. This made a total of 1,050 tubes in a year and a half, not counting about 90 which were put in by the manufacturers.

About this time began the use of a compound furnished by one of the best-known companies in the business. The result was apparently to transfer some of the trouble from the tubes to another part of the boiler where there had been no trouble before. A sediment of black mud formed a scale which caused blisters and tube failures at those points. In June, inspection showed bad corrosion and pitting in all parts of the boiler, and 960 tubes were requisitioned. By October, 1913, the total work orders for boiler repairs on that plant amounted to £3,200, or nearly 12 per cent. of the first cost of the boiler plant. Three different special formulæ for compounds submitted by the same chemical company had been used, but as things were going from bad to worse, the use of the special compounds was discontinued.

In the fall of 1913, with a fine steam plant in a very critical condition, 1,160 tubes out of 3,360 had been replaced and there was no end in sight. A new expert was called in, who began by suggesting the conventional methods of zincs and paints, and that perhaps electrolysis was to blame, although everything had been kept carefully insulated. The result was no better than before. About that time the author was handed the August, 1912, number of the Journal of the American Society of Naval Engineers, which gave an account, by Frank Lyon, Lieutenant-Commander U.S. Navy, of what seemed to be a highly significant development in boiler trouble treatment. In the course of his article, Commander Lyon said: "The writer has no hesitancy in saying that any boiler, using any water, can be kept from corrosion for any length of time." Having been brought up to understand that whatever a naval officer says is so, without qualification, the salvation of the Fruitvale boiler plant appeared to be within reach.

The result of Commander Lyon's investigations was the development of the Navy Standard Boiler Compound. This compound is composed of sodium carbonate, trisodium phosphate, starch, and tannic acid. The sodium carbonate takes care of any chemical reactions and renders the solution non-corrosive. The tannic acid and starch are added to prevent the formation of scale, the action being to hold the impurities in suspension in a colloidal state. The trisodium phosphate prevents the rise of the surface tension of the solution and consequent priming caused by the impurities in the water, and by the application of the other ingredients in the compound. In using this compound to prevent corrosion a sufficient quantity must be added to each boiler to render the alkaline strength of the water in the boiler 3 per cent. of normal or above, and the alkaline strength must be maintained in each boiler. The compound may be purchased from the Government Contractor for about one-half the cost of the ordinary compounds.

On March 4th, 1914, the first boiler was placed under treatment with the Navy Standard Compound. By March 26th it was in use in all of the boilers. As illustrating the results, the record of tube replacements month by month is most significant. In 1912, 690 tubes were replaced; 858 in 1913. In January and February of 1914 there were 229 tubes replaced in the two months, or at the rate of 1,374 a year. The treatment, as stated above, was begun on March 4th, and was in all the boilers on the 26th. Thence the record stands: In February, 171 tubes replaced; March, 24; April, 15; May, 2; and from May, 1914, to June, 1915 (date of writing), not one has been replaced for failures. There have been 13 tubes replaced since May, 1914, but they have all been replaced because they had to be taken out to get at something else, or by reason of obvious defects.

As to the money saved by the introduction of this method: In 1912 it cost in labour and material £1,160; in 1913, £2,050; in the first six months of 1914 it was £316; and since then the expense will hardly come to £20 a month for everything considered, that is, the ordinary wear and tear of the plant, washing of boilers, &c. In addition to this, extra labour in the plant (made necessary by the failing tubes), to the extent of £36 a month, has been discharged. The treatment as practised there costs about £16 a month, depending upon the amount of compound used. There is no scale in these boilers; they are absolutely clean. Below the water line they show clean black iron; above, a thin coating like whitewash.

The first two months' operation at the Fruitvale power station with the navy compound in use showed such very satisfactory results that the management ordered a trial of the method on probably one of the worst locomotive water districts in the company's service, namely, that part of the San Joaquin Division between Bakersfield and Mojave, known generally as the Tehachapi Pass. Mr. R. S. Twogood, assistant engineer in the office of the consulting electrical engineer, was detailed on this work and for nearly a year he has given practically his entire time to this demonstration. The following is an abstract of his contribution to the discussion at the December (1914) meeting of the San Francisco section of the society, when this subject came up for a general discussion.

On July 21st, 1915, a compound test was started on freight Mallet locomotive No. 4,031, operating over the Tehachapi

* Paper presented at the annual meeting of the American Society of Mechanical Engineers, New York, December, 1915.

Pass. The locomotive was just out of shop. It had a new set of flues, was free from scale, with the exception of a thin deposit on the crown sheet and crown and stay bolts that were not removed during back shopping. The engine was left in chain-gang service. At first an effort was made to carry the alkalinity at 3 per cent., but so far the best results have been from 0·5 per cent. to 0·7 per cent. normal alkalinity. Several things in the design of the locomotive, especially the Mallet, contribute to this result: for example, a very small steam space and steam dome; no perforated dry pipe to collect steam from all parts of the boiler; constant surging of the water due to the motion of the locomotive; sudden opening of the throttle and consequent great demand for steam, which reduces the pressure on the surface of the water under the throttle and causes it to rise and pass over into the steam pipes. Also, the water used for locomotive purposes in this district contains a large amount of solid matter which would tend to cause priming.

One point constantly in mind was to find some treatment in which one man could be made responsible, without having to depend on the engineers and firemen. This means that the boiler must be treated at engine turning points. At first the chemicals (enough for the entire trip) were put into the tender tank, thence to pass with the feed water through the injector, feed-water heater, and into the boiler. By this method the desired percentage of normal alkalinity in the boiler was not reached until one tank of water (10,000 galls.) had been used. Also, considering the fact that the tank capacity is much greater than the boiler capacity, the tank alkalinity was very low. This low alkalinity, though strong enough to bring out some solid matter, did not furnish sufficient tannic acid and starch with the standard proportion of chemicals to prevent this solid matter from forming scale. In the injector, where the cold water came in contact with the steam, and later where the warm feed water came in contact with the hot boiler water, some scale was formed. After this was noticed no more compound was added to the tank, but was pumped, in a concentrated solution, through the injector. This gave at once the desired percentage of normal alkalinity in the boiler. There has been no further trouble with scale.

The water from Bakersfield to Mojave averages about 3lbs. of scale-forming matter per thousand gallons. A Mallet locomotive in a helper trip from Bakersfield to the Summit and return will use from 30,000 galls. to 35,000 galls. of water, which means about 100lbs. of scale per helper trip. With the present method of treating, 20lbs. of compound are pumped into the boiler before leaving Bakersfield yards. This gives an alkalinity of about 0·6 per cent., and as this percentage remains approximately constant between engine turning points, it is possible to treat the boiler for an entire trip before it leaves the round-house.

If too little compound is used the precipitate is fine and does not settle readily; but when the amount is sufficient the precipitate is large and flaky and settles very rapidly. This makes it easy to clear the boiler of some of the solid matter by blowing down after the engine has been standing on the siding a few minutes awaiting passing trains. Present practice is to wash the boiler every second trip. A large percentage of the solid matter runs out with the water while draining the boiler and the rest is easily washed out. The solid matter has no tendency to cake, but will remain indefinitely in the form of a soft brown mud. It must be borne in mind that the frequency of washing is a function of the amount of solid matter in the water and the amount of water used.

Prevention of corrosion and scale formation was the main endeavour, and yet another result was obtained, just as important. Absolutely no boiler troubles were encountered during the first four months of the test, and then the record was broken only by a minor leak, a record that gives some idea of the importance of keeping the boiler free from scale and thus prevent the high and uneven temperatures in the steel which cause the opening up of joints.

It is standard practice to carry from 1,000lbs. to 1,500lbs. of sand on a Mallet locomotive to cut the soot from the inside of the flues. Why is it not just as important, for good steaming, to use some method to keep the outside of the flues free from scale?

The ingredients of the navy compound originally were proportioned for use in stationary and marine boilers, and at an alkaline strength of 3 per cent. normal. The 10 per cent. of trisodium phosphate was added to prevent light water. The locomotive type of boiler, in general, shows a greater tendency to foam than other types of boilers and should, therefore, have a stronger non-foaming reagent. In cutting down the alkalinity from 3 per cent. of normal to less than 1 per cent., the amount of trisodium phosphate has been greatly decreased with good results. The amount required seems to vary so much with different runs and conditions that as yet no decision can be made as to a definite amount for general use.

A new water was obtained at Bakersfield in January that is a great deal better than the old, as far as content of incrustating matter is concerned, but it is very light. Foaming and priming became so bad in one of the passenger locomotives that the water in the glass rose as much as 8in. when the throttle was open. No compound of any kind had been used in this boiler. Six pounds of trisodium phosphate (no compound) was then put in the boiler through the injector just before the engine left the roundhouse for each trip. There has been no foaming on this locomotive since.

During the early part of the test on Mallet No. 4,031 some light water and foaming were experienced. It was feared at that time that water, passing over, would loosen superheater units and high-pressure steam piping, and would cut cylinder bushings and packing, but these fears proved to be ungrounded. The engine has made more miles between shoppings for boiler repairs than any other Mallet operating out of Bakersfield.

On this division, where the water is poor, practically all of the locomotives are back-shopped on account of the boiler and not the machinery. The present indications are that the use of this compound will make the life of the boiler longer than that of the machinery. During the last month the use of this compound has been extended to all freight Mallets (seven) operating out of Bakersfield. Some of these had been in service for several months and large quantities of scale had formed. The cutting of this scale made very dirty boilers, causing frequent blowing and boiler washing. After two or three weeks, scale from ⅛in. to ⅜in. thick came off in large quantities, which proves that the compound will cut the old scale, but this action causes such dirty boilers that such procedure cannot be recommended. By the practice outlined above, a clean boiler can be kept clean and operated with success, using water classed by boiler people as very poor.

The results in the Fruitvale power station boilers caused prompt steps to be taken to extend the use of the compound to other stations either operated or controlled by the Southern Pacific Company. The Associated Pipe Line Company operates an oil pipe line from the oil fields in the southern end of the San Joaquin Valley to tidewater near San Francisco. On this pipe line are 30 steam pumping stations equipped, some with three and some with four 250 h.p. water-tube boilers. The feed water is of practically every known grade from good to very poor, and nearly every known type of boiler compound has been used from time to time in the worst of these stations. Mr. E. B. Partridge, junr., superintendent of the pumping plants in the fields, came to Fruitvale power station for a study of the method. He began his investigation in the most sceptical frame of mind and he introduced the compound first into a station where, as he said, it could do the least harm. Eight months later, at the December meeting of the San Francisco section of the society, where the subject was discussed, he gave an account of his experience which is here briefly summarised: In the 30 different pumping stations there were 30 different kinds of water, with a solid content running from 6 gr. to 230 gr. per gallon. In the first station, a three months' trial of the compound showed that a turbine tube cleaner was no longer necessary, because the boiler was readily washed out and cleaning would not be required oftener than every three months.

These results were confirmed at the next station where the compound was tried. It was then introduced in a station which most of the feed-water experts in the State had turned down as impossible. The water carries 230 grains to the gallon. In these boilers 2½in. extra-heavy boiler blow-off nipples corroded away in from three to four months and 3in. extra heavy feed-water lines pitted through in the same length of time. Nearly every known variety of boiler trouble had been experienced at this plant, but the navy compound eliminated corrosion and precipitated the solids in a soft slushy form easily washed out. Owing to the unusually large quan-

tity of solid matter in the water, however, it was necessary to blow the boilers every hour and to clean every ten days.

At another station where corrosion very similar to that in the Fruitvale boilers had been experienced from the start and all kinds of compounds had failed to relieve the trouble, the navy compound was introduced. Up to that time they had used No. 9 gauge seamless tubes in the bottom boiler rows, and No. 10 gauge special spellerised tubes in the upper rows, but none of them lasted more than three months. Feed lines, blow-off pipe lines, boiler drums and headers, together with the tubes, were all affected by corrosion; but the navy compound straightened out all their trouble in this station precisely as in all the others. In order to have further verification, pieces of new tubes were hung in these boilers and after three months they showed not the slightest signs of corrosion.

In general, Mr. Partridge found that when he commenced to use the compound there were a great number of tubes which had been badly pitted and that these failed gradually, but they held up surprisingly well, considering their condition. Only a very few of these old tubes have been lost and none that were put in just prior to the introduction of the navy compound treatment. He found that to get results it is necessary to work intelligently and not at all in the old haphazard fashion. He detailed an inspector on the work who travels from station to station, not only to see that the compound is being properly used and in sufficient quantity, but also to instruct engineers and to quiz them as to the results they obtain.

At every pumping plant a printed form is filled out and mailed to the general office every morning. From these Mr. Partridge keeps a close supervision over all of the plants. The reports show how much compound is used; what percentage of alkalinity is carried; how often the boilers are blown, that is, a bottom or a surface blow; when any particular boiler is cut in or cut out, and why; and the condition of the boiler when it is opened for cleaning. The importance of these results is best understood by engineers who know the operating conditions of an oil pipe line, where all the pumping plants are in series from one end of the line to the other, and a delay or a stoppage at any one station affects the output of the entire line, and consequently the earning capacity of the whole property.

The use of the navy standard boiler compound was discussed in a preliminary way at a meeting of the San Francisco Section, after which it was suggested to the author that it would be well to go slow in using navy compound, for the reason that some vessels had experienced such serious damage to their boilers from it as to cast discredit upon this method of boiler treatment. The substance of the statement was that for some years evidence has accumulated to show that under certain circumstances the use of sodium carbonate or sodium hydrate in boilers makes the steel brittle and causes failure of the joints by cracks; that at present it is impossible to state how or why the action occurs, but it is possible to name the circumstances under which it is likely to occur, the characteristics of the cracking when it does occur, and the principal cases that have come under direct notice.

Briefly, the theory advanced to the author as to the trouble is as follows: That sodium carbonate is always partially converted into sodium hydrate when in solution under boiler temperature, so that it makes no difference whether the carbonate is used in the beginning, or caustic soda, or both, as sodium hydrate will always be present sooner or later. When either of these substances is used for the treatment of scale, no trouble from the cracking of the steel is likely to occur, because they react with the scale and there is little or no excess hydrate. Where cracking has occurred it has always been true that free hydrate has been present in the boilers in the absence of sulphate; so that the statement is warranted that whenever sodium carbonate or sodium hydrate is introduced into a boiler in the absence of substances reacting with them, brittleness will result sooner or later. Cases have been known in which the brittleness approaches that of neat cement of the same thickness as the plate. It occurs only in the seam of the boiler, either due to the fact that the joints are at higher stresses here than in the rest of the plate, or that the joints are the only place in which this solution can concentrate, and it is known that unconcentrated solution does not attack steel at all. The cracks that result are distinguished from ordinary forms of cracking by the following characteristics:—

They are more fully developed at the surfaces of the contact of the joints than they are at other surfaces, so that a crack at a rivet hole will often measure $\frac{3}{8}$in. on the contact surface of a $\frac{1}{2}$in. plate without showing at all on the other surface; in other words, the surface of the crack itself is usually triangular, with the base of the triangle on the contact surface. They usually originate at the rivet holes and show scarcely any tendency to follow the lines of stress. Running from adjacent rivet holes, two cracks will often pass each other and, after passing, join, leaving an island in the plate; that is, the cracks show no strong tendency to join each other. They change their direction sharply and often, to an extent of 90°; they are always unaccompanied by any elongation of the plate; and finally, they are always, of course, below the water line.

The statement made to the author gave also a number of cases of such defective plates. Among others were named the boilers of the U.S. torpedo boat destroyer "Aylwin," wherein occurred a fracture of one drum, and cracking of one or more drums of three boilers out of four; also the U.S. coast guard cutter "Unalga," where a cracking of one drum out of two in a period of operation of about 14 months was noted. The statement concluded by a note to the effect that in the case of the coast guard service, an order had been issued discontinuing the use of the navy compound.

Because the treatment, at least in this form, originated in the Navy Department, because the "Aylwin's" boilers were cited among others as having failed from this cause, and because the navy boilers are operated in general with water that is practically free from sulphates, the statements with reference to navy experience were investigated as fully as possible, and the following facts were developed:—

The use of navy compound has not been discontinued in the navy, but the compound is used ordinarily only in sufficient quantity to maintain the water in the boiler at a low alkaline strength, and not above $\frac{1}{2}$ of 1 per cent. normal, the point at which corrosion changes in character from general corrosion to local corrosion or pitting. In a steaming boiler no difficulty is experienced in maintaining the alkaline strength of the water at or above 3 per cent. normal; but naval boilers are idle during a large part of the time, and owing to the fact that the compound does not remain in solution in idle boilers, but settles to the bottom, the alkaline strength of the water in the upper part of the boiler frequently falls between the limits of 1 per cent. and 2·5 per cent. of normal. As is well known, the effect of this alkaline strength is to promote corrosion in its most dangerous form—local corrosion or pitting.

The early experiments with the boiler compound determined the facts that good steel will corrode almost evenly over its entire wetted surface when placed in distilled water, and that as boiler compound is added to give the water a low alkaline strength, the rate of corrosion is somewhat decreased, but the character of the corrosion remains the same. Therefore, low alkalinity inhibits all but a light general corrosion, which is so small in amount that its effect may be disregarded for practical purposes. Further, since the navy uses distilled water to a large extent, only small quantities of scale-forming substances are ever present in the boilers, and hence large amounts of boiler compound are not required to prevent the formation of scale.

In the case of the "Aylwin's" boilers the Naval Engineering Experiment Station conducted an extensive investigation of the rupture of the drum, and authority was granted for a representative of the manufacturer to be present during the tests. The conclusions of this investigation were that no experimental or other evidence indicated that the failure of the "Aylwin's" boiler was due to the use of boiler compound containing sodium carbonate or sodium hydrate. It is needless to say that any condition of design or construction that causes leaky seams which can be made tight only by excessive caulking might possibly produce brittleness in the metal of the plate. The White-Forster boiler installed in the "Aylwin" class has D-shaped water drums, similar to the Yarrow type.

With reference to the "Unalga" as another vessel having had trouble of a similar nature, not enough is known at the present time upon which to venture a statement as to the cause of failure. It is known, however, that the cracks in the steam drum plates of these boilers are similar to those observed in the "Aylwin's" lower drum plates; that the manufacturer of the boiler has conducted tests of the material, and that at the suggestion of the company the Naval Engineering Experiment Station will soon begin an independent examination and

investigation of the material with a view to determining the cause of the peculiar conditions existing. It has also been learned that boiler compound in considerable quantity was used in this boiler, and that another vessel with a duplicate boiler, but in which only small quantities of the compound were used, has not had trouble.

APPENDIX.

SYNOPSIS OF INVESTIGATIONS BY FRANK LYON, LIEUTENANT-COMMANDER U.S. NAVY.*

From July, 1896, to August, 1899, Commander Lyon was assistant engineer, U.S.S. "Oregon," and for the greater part of the time was in direct charge of her boilers. The feed water was kept in practically an open tank and was kept so strongly alkaline as to render it unfit for ordinary purposes. In this vessel corrosion of boilers was almost unknown.

From May, 1906, to May, 1909, Mr. Lyon was senior engineer officer of the U.S.S. "New Jersey." Troubles from corrosion were experienced throughout the three years. The corrosion was most noticeable in the piping in which the water was heated more or less between its entrance to and exit from the system.

The "Oregon" had fire tubular boilers, and the "New Jersey" Babcock and Wilcox boilers. The water in the latter was kept slightly alkaline, but owing to fear of priming in these small drum boilers, it was never kept as alkaline as that in the "Oregon's" boilers. It was felt that every effort to prevent corrosion and to keep the boilers clean had been made, yet destructive local corrosion was going on and increasing in effect in spite of the zincs, non-acidity of the water, cleaning and other efforts to stop it. The navy regulations had been followed, and experiments made, yet Mr. Lyon had failed in every particular to stop corrosion of metals having their surfaces in contact with water, and he was detached from that duty and left, knowing that there was something woefully wrong in the methods he had pursued and with the general methods of treating corrosion on shipboard.

With this excellent grounding in a knowledge of the effects of corrosion, he began at the Naval Engineering Experiment Station an experimental investigation of the problem of preventing corrosion. Tests were made in distilled, sea, and brackish waters, in diluted sea and brackish waters with jars open and closed; in steel pots, glass jars, and in a boiler. Very soon after starting this investigation it was seen that in the untreated distilled or in fresh waters the specimens of steel corroded all over; that as the concentrations† increased, the rate of corrosion at first decreased slightly and then began to increase. In the concentration where the rate showed an increase there were always evidences of local corrosion or pitting, and as the concentrations increased the rate of loss increased to a maximum, then fell rapidly to zero and remained there, the areas of local corrosion becoming smaller and more pronounced until they disappeared altogether in the concentration in which the loss was zero.

The concentration whose strength is just below the one in which local corrosion or pitting first appears, he called the lower-limit concentration; the one in which the rate of corrosion is a maximum, the critical; and the one just above the one in which the last signs of corrosion appear the upper-limit one for the metal tested.

In general the fundamental fact was established that if the solution is kept sufficiently concentrated with sodium carbonate, corrosion is inhibited. That is the sum and substance of it. Also, that the order of magnitude in which corrosion occurs in distilled-water solutions in the normal concentration of sodium nitrate, chloride, and sulphate was in about the order of the strength of the acid radicals. The upper and lower limit concentrations in those solutions in which they are found, vary with the metals immersed, and with the conditions of the surface of the metal in contact with the solution, both with regard to impurities in it and to the physical treatment it has received.

The last two points are very important to remember as accounting for local corrosions; and also this vital point: That the rate of loss in the critical concentration is greater than that in the untreated water. In other words, it is better not to treat the water at all than to treat it near the critical values, and this can be done very readily by pouring compound into a boiler without paying attention to what the concentration is in the boiler, a fact that demonstrates the necessity for the individual testing of the water in the individual boiler under steaming conditions.

The limit and critical concentrations of the following solutions for one grade of steel were determined very carefully. Expressed in percentages of normal strength in distilled water, they are:—

Solution	Upper limit	Critical	Lower limit
Sodium carbonate (calcined)	2·6	0·8	0·16
Caustic soda	2·6	0·8	0·16
Lime	2·6	0·6	0·15

These are the three salts used extensively in boiler treatment. They have practically the same characteristics as regards solution pressure, which is the measure of the tendency to corrosion.

Further work along these lines with open jars showed that the concentration of lime solutions weakened very rapidly, while those in caustic soda, sodium carbonate, disodium phosphate, and the chromates maintained or increased their concentration as the water evaporated. Solutions of lime water exposed to the air may be non-corrosive to steel one day and corrosive the next, due to the absorption of carbonic acid from the air, while if the upper-limit concentration of sodium carbonate is made, steel thrown in it will not corrode until the concentration is brought below the upper limit by some external means. The English of that is, use sodium carbonate if possible; do not use lime unless forced to, and when lime is used be careful not to work near the critical value.

Commander Lyon found that steel connected to copper by a good metallic conductor does not corrode in an upper-limit concentration of sodium carbonate, lime, caustic soda, or disodium phosphate. In similar concentrations air, oxygen, carbonic acid gas, graphite, zinc oxide, mill scale, and other supposed exciters of corrosion have no effect upon steel or iron until the concentration is reduced below the upper limit for that steel. Steel was suspended in a glass basin in, and above, the limit concentration of sodium carbonate, and pure oxygen was blown under it in such a way that 60 bubbles a minute impinged on the steel and passed up along its sides; this continued for eight days, and no signs of corrosion were evident, and there were no losses of weight. This was continued for 15 days longer, using air instead of oxygen, with the same result.

Zinc, being of higher potential than iron, will corrode in an upper-limit concentration for iron or steel. It was found that the upper-limit concentrations for all irons and steels was about 2·6 per cent. normal alkaline strength of sodium carbonate and of caustic soda solutions, in distilled and in sea water. The highest concentration of any of these chemicals in which corrosion was found is 2·5 per cent. of normal.

With pure feed water, sodium carbonate, and trisodium phosphate, properly proportioned, will stop corrosion and priming if enough of the mixture is used. If impure water is used, then sodium carbonate, trisodium phosphate, and cutch (containing tannic acid), when used in the right amounts, will stop corrosion, prevent priming, and also prevent scale from forming unless the saturation of sludge gets too high. Such a mixture is the navy standard boiler compound; and if by the use of this compound the water in the boiler is always kept at a concentration of or above 3 per cent. normal alkaline strength, no corrosion will take place, no scale will form, and the water will be no more likely to prime than it would be if it were untreated.

The ingredients of the navy compound are intimately united by thorough digestion, dried, finely powdered, and well mixed. They are readily soluble in water. The compound must show on analysis at least 76 per cent. of anhydrous sodium carbonate (Na_2CO_3), 10 per cent. of trisodium phosphate ($Na_3PO_4.12H_2O$), 1 per cent. of dextrine or starch, and sufficient cutch to yield at least 2 per cent. of tannic acid, the remainder to consist of water and only such impurities as are common to the ingredients.

These investigations demonstrated why the boilers of the "Oregon" showed no signs of corrosion in three years, and why those of the "New Jersey" were considerably corroded in the same time. In the one the corrosion had been prevented

* The Journal of the American Society of Naval Engineers August, 1912. Navy Department, Washington, D.C. Many of the paragraphs above which refer to Mr. Lyon's work are abstracted liberally from his article.

† In this discussion, the concentrations mentioned are the alkaline salts in the water expressed in percentages of "normal solution." Equal volumes of normal solutions will just satisfy a chemical reaction completely without any surplus of reagents remaining on either side of the equation.

by keeping the water strictly alkaline; in the other it had been materially aided by an insufficient degree of alkalinity. Mr. Lyon's conclusions are tersely expressed as follows: "The writer has no hesitancy in saying that any boiler using any water can be kept free from corroding for any length of time if treated with soda, and if its concentration is maintained at or above 3 per cent. normal alkaline strength. If the water is not to be kept sufficiently alkaline, it had better be kept neutral."—A statement that is absolutely borne out by the results of his treatment as applied at the Fruitvale power plant according to his method.

PERMANENT GRAPHITE MOULDS FOR METALS AND ALLOYS.

A PATENT has recently been granted to Mr. Charles Vickers, Niagara Falls, N.Y., on a permanent mould made of graphite for making non-ferrous metal castings, which he has assigned to the Titanium Alloy Manufacturing Company, of Niagara Falls, N.Y., with which he is affiliated. The mould is made of graphitised carbon used preferably in the form known as artificial graphite. This is exceedingly refractory and is resistant to high temperatures, and, therefore, the mould can be used repeatedly for making castings. This substance is one of the most rapid heat conductors known, and consequently has a rapid chilling effect on the metal, preventing liquation attributable to slow cooling of the metal in the mould.

It is well known that the production of castings from alloy comprising two metals, the one of which is of a high and the other of a relatively low melting point, a separation throughout the casting into alloys of different composition takes place. Such alloys having the highest fusing point solidify first and the entire mass becomes only gradually solid by further cooling. Therefore, when freezing or solidification commences, an alloy rich in the metal of the higher melting point and poor in the metal of the lower melting point will first separate as a solid, and this is followed by the solidification of various other alloys containing progressively less of the former metal and more of the latter, the last alloy to separate and to solidify being proportionately very rich in the metal of the lower melting point and correspondingly poor in the other. The resulting casting thus lacks homogeneity and consequently is weaker in spots than it should be. The graphite mould, it is claimed, overcomes this liquation and causes the rapid cooling of the metal.

It also is pointed out that graphitised carbon is capable of having its heat-conductive property modified and adjusted to meet the requirements of different metals or even different parts of the same casting. For example, when meeting special requirements, Mr. Vickers has constructed these permanent moulds from graphite, either artificial or natural, with a binder such as tar or pitch, which then was baked in a furnace similar to the procedure in ordinary carbon manufacture. When a heat conductivity was imparted to the mould too great for successful use in certain forms of castings by this process, he adjusted the heat conductivity to that required by adding to the constituent mixture a certain amount of amorphous carbon, determined to be sufficient to reduce the heat conductivity of the mould. He also states that he can form his permanent moulds wholly out of the amorphous carbon and then graphitise them in an electric furnace. Here again he is able to adjust their heat conductivity as required. By correspondingly adjusting the temperature of the furnace, he is able to regulate the extent of the graphitisation of the amorphous carbon and thereby correspondingly control the heat conductivity of the resulting mould. The heat conducting properties of the permanent mould can be adjusted locally by varying its thickness at different points or zones, corresponding to the thicker and thinner parts of the castings, and by this means he ensures more rapid heat withdrawal from the thicker parts and less rapid from the thinner parts of the mould, thus ensuring substantial uniformity of heat-withdrawal from all parts of the casting at the same rate and an equal amount during a given time.

In cases where a permanent mould is not required, a temporary mould can be made from a form of graphite obtained by the decomposition of silicon carbide or other similar carbides, since this form possesses plastic, coherent properties when subjected to pressure. Also, the temporary mould may be made from a mixture of graphitised carbon and moulder's sand, regulating the proportions so as to impart to the mould the degree of heat conductivity best suited to the particular kind of casting desired. For the purpose of demonstrating the influence of the graphitised carbon permanent mould on the physical properties of non-ferrous metal castings, Mr. Vickers made a series of tests with an alloy containing aluminium 92 per cent. and copper 8 per cent. From this alloy he made castings from the same heat in four different moulds made respectively of sand, amorphous carbon, iron, and graphitised carbon. The results of these tests follow:—

Casting.	Ultimate Strength, Lbs.	Per cent. Elongation.	Per cent. Reduction.
In sand mould	12,300	1·0	0·7
In amorphous carbon mould	17,700	1·8	1·3
In iron mould.	25,500	3·5	4·1
In graphitised carbon mould	26,300	3·8	4·4

The four substances thus employed are superior to each other in heat conductivity as moulds in the order named, that of sand being the least and that of graphitised carbon the greatest. Similar tests with other alloys gave analogous results. Tests also were made on temporary moulds consisting of a mixture of sand with graphite as compared with that of sand moulds, the alloy used having consisted of 92 per cent. aluminium and 8 per cent. copper. The ultimate strength of the castings made in the sand mould was 21,650lbs. and that from the graphite and sand moulds 26,780lbs.

In view of the rapid chilling properties of the graphitised carbon mould, it is necessary to employ risers or feeders of ample size made of a lower heat-conducting substance or mixture than the mould itself. The riser is made of moulder's sand, and by its use the casting is continuously fed until solidification takes place. In casting in sand moulds, for example, for some alloys it has been found necessary to have the riser fully as bulky as the casting, and in making some alloys, such as aluminium bronze, the ratio of bulk of riser to that of the casting has been as high as 1½ to 1. However, with the use of the graphitised carbon permanent mould the relative proportions of riser to casting are materially reduced and in usual practice it does not exceed one-fourth of the bulk of the casting. This permanent mould has been found advantageous in casting copper, nickel, lead, zinc, aluminium, and many alloys comprising some of these metals, such as German silver, brass, bronze, gun-metal, and the white metals, and it also has proved useful in casting ferrous metals and their alloys.—"The Foundry."

THE TUNGSTEN-MOLYBDENUM SYSTEM.

THE tungsten-molybdenum system is discussed by Dr. Frank A. Fahrenwald, of Cleveland, Ohio, in a paper to be presented at the Arizona meeting of the American Institute of Mining Engineers in September. The results of an investigation of alloys of these two elements, in which methods were employed that avoided the usual difficulties accompanying high-temperature alloy investigations, are summarised as follows: (1) By compressing the mixed reduced powders of tungsten and molybdenum into briquettes and then heating with an electric current in an atmosphere of hydrogen, alloys of this series were prepared varying in composition from 100 per cent. tungsten to 100 per cent. molybdenum. (2) The solidus curve for the series was located by means of optical pyrometer temperature measurements and checked by comparing the fusing current with a standardised wattage-temperature curve. (3) The equilibrium diagram for this series shows no critical points, appearing as resistance fluctuations, corresponding to a separation of a new phase. Its construction has been based upon this fact and upon results of microscopical analysis. (4) Curves for hardness and for equiaxing temperatures are smoothly convex, being typical of an uninterrupted series of solid solutions (mixed crystals). (5) As a result of thermal and microscopical analysis, the metals tungsten and molybdenum are reported to be completely isomorphous. (6) All alloys of this series are malleable and ductile under proper conditions.

LIGHT AND ILLUMINATION.*

BY DR. CHARLES P. STEINMETZ.

(*Concluded from page 106.*)

THE problem of producing light from heat, by combustion or by an electric current, therefore, involves raising the light-giving body to as high a temperature as possible, because the higher the temperature the greater is the percentage of the total vibrations emanated that fall within the visible range. But even at the very best, if it were possible to make use of a temperature of 5,000° C., we could not get more than 10 or 12 per cent. of the vibrations as light. Unfortunately tungsten evaporates at between 3,000° and 4,000° C., and other available substances vaporise at still lower temperatures; thus we are prevented in practice from attaining the maximum efficiency possible by radiation due to temperature.

Nevertheless, all the advance in illuminating engineering has been made by utilising higher and higher temperatures. In the beginning, light was obtained through the temperatures obtained by combustion, ranging from lower to higher temperatures according to the combustible used, as flaming pine sticks, vegetable oil, whale oil, mineral oil, kerosene, &c., with an upper possible limit of about 2,000° C., determined by loss of chemical affinity of oxygen for other elements at still higher temperatures. At the temperatures of combustion red, yellow, and at the highest limit, a whiter flame was produced, but all of them of low percentages of efficiency for obvious reasons heretofore given.

Then we came to the electric light. Although higher temperatures than 2,000° C. cannot be reached by combustion, we can go higher by means of the electric current. Attempts at producing light by the electric current were made by heating wire conductors to a high temperature, and the first attempt at an incandescent lamp was with a platinum wire; but platinum melts at about 1,760° C., therefore the efficiency of light production by this means is very low. Then Edison discovered that a wire of carbon—a carbon filament—could be used in place of platinum. Now carbon does not melt, or boil, until a temperature of about 4,000° C. is reached. Consequently it should stand a very much higher temperature in an incandescent lamp than platinum. The old carbon filament lamps were run at about 1,800° C., somewhat above the melting point of platinum, and thus with higher efficiency, and no danger of melting. About 45 watts of electrical energy were required per candle power.

The question arose: Why could not the carbon be operated at a higher temperature and thus at higher efficiency? If instead of running at a temperature of 1,800°, requiring 45 watts per candle power of light produced, the carbon was raised to 2,500°, the candle power would be doubled for the same watts. But the limitation there was, not that the filament melts or boils, but another limitation—evaporation. We know materials can evaporate below their boiling point, for example, that water at ordinary temperatures will evaporate within a few days, and that even ice and snow below the melting point gradually disappear. The carbon filament at 1,800°, way below the melting and boiling point, also slowly evaporated, the carbon vapour being deposited on the lamp bulb. With continuous evaporation the filament got thinner, thereby the temperature went down and the light became less. The deposited carbon vapour also obstructed the light. If the filament were raised to 2,500° C., the temperature would rapidly go down through excessive thinning of the filament by evaporation, and the deposited carbon on the globe would blacken it to such a degree that even the filament itself would only faintly be seen through the glass.

So we were limited as to the operating temperature of the carbon filament because it had to be kept below the melting or boiling point, where the rate of evaporation does not unduly reduce the light production, and efficiency of that production, within a reasonable time, say, 500 hours or so. That was the limitation to the efficiency of the old carbon filament light.

The problem later was to make it possible to run carbon at higher temperature without undue evaporation, and thereby get higher efficiency. Carbon is a rather indefinite body: there is carbon and carbon, for instance, the carbon obtained from bamboo fibre, the carbon from silk strands, and that from cellulose, and so on. The material obtained by carbonising fibre evaporates rather rapidly, but carbon deposited from gasolene at high temperature is of another kind, which does not evaporate so easily, and thus can be run at higher temperatures. Therefore, if a shell of carbon from gasolene vapour is deposited upon the carbon filament of old producer from fibre, it can be run at higher temperature with equal falling off in light and blackening of globe, but we will get a higher efficiency, and this was done.

About 10 or 12 years ago still another useful modification of carbon was found, represented in the so-called metallised carbon filament, which somewhat possesses the strength and resiliency of a hard-drawn metallic wire, and evaporates still less rapidly than the earlier carbon; therefore it can run at a higher temperature. This carbon is used in the filaments of the so-called "Gem" lamp, which can be operated at about twice the efficiency of the old carbon lamp with the same rate of evaporation, the same rate of blackening, and the same light.

But even the temperature of the metallised carbon in the "Gem" lamp is still way below the temperature of boiling. We can produce light by running the temperature of carbon up to the limit, that is, to the boiling point, nearly 4,000° C. We cannot do it with a filament, however, but must use the arc lamp, in which the current passes through hot vapour in the space between two slightly separated carbon rods and raises the tip of the positive carbon to the boiling point. The light emitted has the efficiency that would be obtained at about 4,000°; all the evaporation takes place at the positive carbon, and probably 8 or 10 per cent. of all the vibrations radiated are visible. Thus the arc lamp would give a very high efficiency were it not that an excessive amount of heat energy is conducted off by the carbon rods and carried away by the air. That is the main, and a serious loss.

The problem thus became one of finding something that can stand higher temperatures than carbon under all practical requirements. Tantalum, osmium, and tungsten are all metals of extremely high melting points, but they have a characteristic advantage over carbon in that their rate of evaporation is much less at high temperatures. The carbon filament in the old incandescent lamp evaporated, although it was operated at a temperature much below the boiling and melting point. Tungsten, on the other hand, can be run up high in the temperature scale nearly to the melting point with very little evaporation. So you see that the melting point, or boiling point, and the evaporating point have no necessarily fixed relation for different substances. Benzine and water, for example, boil at about the same temperature, but a plate full of benzine will evaporate long before a plate full of water. If carbon and tungsten are kept at the same high temperature, the carbon will evaporate rapidly while evaporation from the tungsten will be very much slower. Therefore we can run tungsten at much higher temperature than carbon with the same evaporation, although really the tungsten would melt before the carbon. Carbon will stand higher temperature, but it then evaporates too rapidly.

In respect to the three metals mentioned, osmium proved very good as the illuminant in a lamp, but is too rare to be generally used. Tantalum gave good results, having a higher resistance than carbon, but has been superseded by tungsten because the melting point of the latter is much higher, and it can thus be run at a higher temperature, and it is now used in all lamps having metallic filaments. The so-called "Mazda" is a tungsten lamp. Since the tungsten lamp can be operated at a much higher temperature than any carbon lamp, a greater percentage of all the vibrations produced come within the visible three-quarter octave. The carbon lamp requires three watts per candle, while the tungsten lamp requires only one watt because with the carbon filament only three-fourths per cent. of the total vibrations are in the visible range, while with the tungsten burner we get about 2 per cent., or about three times the percentage.

Two per cent. is, however, very little. Most of the vibrations are still outside the visible range, either too slow or too fast. So the further problem has been somehow to get a still higher operating temperature. In the carbon and tungsten lamps a vacuum has been used. Naturally the lamp having a carbon filament must at least be exhausted of air to prevent its combustion, but that is not the fundamental reason for the

* Paper presented at a joint meeting of the electrical section of the Western Society Engineers and the Chicago section of the American Institute of Electrical Engineers, October 26th, 1915.

vacuum because the lamp bulb might be filled with a gas in which carbon will not burn, such as nitrogen, hydrogen, or argon. But to maintain the carbon filament in such a gas at the temperature it would have in a vacuum would require much more energy. By conduction and convection the gas will carry away a very large part of the energy supplied to the filament, which will be given up to the glass globe and dissipated uselessly, and therefore a much greater energy consumption is required, if the filament is to be maintained at the proper temperature. Without the extra supply of energy the filament would not attain a light-giving temperature. So the reason for the vacuum in incandescent lamps has been to avoid the enormous loss of energy through heat conduction and convection where the globe filled with a gas.

The use of a vacuum, however, is disadvantageous because it facilitates evaporation, and thus sets a lower and less efficient limit to the temperature to which in practice the filament should be raised, even though far below the melting or boiling point.

Now, the boiling point and rate of evaporation of water at other low temperatures depend upon the pressure. At ordinary atmospheric pressure water boils at 100° C.; at higher pressure it will boil at higher temperature; and at lower pressure it boils at lower temperature. In a vacuum water may boil at the melting point of ice, and it the vacuum is excellent, no water will be present, the boiling point drops below the freezing point, and the ice passes directly into water vapour. If, likewise, in the incandescent lamp we can decrease the evaporation by lowering the boiling point, it follows that the vacuum is a disadvantage because without the vacuum, evaporation and blackening would be very much less at the same temperature.

Now, suppose that instead of having a vacuum in a 100-watt tungsten lamp it is filled with inert gas, say, nitrogen at atmospheric pressure. To maintain the filament at the same temperature as before will require more energy because much of the heat is carried away by the gas, the pressure of which, however, will cause the evaporation to be much less, therefore the filament can be raised to a still higher temperature with an evaporation no greater than with a vacuum. The pressure has raised the boiling point and reduced the evaporation rate for equal temperatures.

Assume the evaporation in a vacuum to be such as to limit the life of the lamp to 1,000 hours at the temperature produced by 100 watts, then with nitrogen at atmospheric pressure we could use, say, 200 watts with the same rate of evaporation and blackening. But this would raise the temperature, so that while 100 watts will give 200 candles, 200 watts would give 600 candles, were it not that the nitrogen carries a lot of heat away from the filament. Consequently an additional 100 watts must be supplied to make up for this loss and raise the temperature sufficiently to give the 600 candles. In this way the candle power of the lamp has been increased from 200 candles with an expenditure of 100 watts to 600 candles for 300 watts with the same evaporation, blackening, and life, which means an increase in efficiency over the vacuum lamp from one candle per watt to two candles per watt.

Now, suppose we take another lamp, say, one requiring 20 watts with a vacuum. If filled with nitrogen, the temperature could be raised, probably not so high as to get six times as much light, because a 20-watt filament is so thin the evaporation that occurs, even at the lesser rate due to the pressure, would wear it away too fast. Furthermore, the percentage of energy lost through the gas is very much greater, because the surface of a thin filament in contact with the gas is much larger compared with its volume than in the large filaments of lamps of high candle power. Whether the loss of energy due to the gas will be more or less than the gain made by the higher temperature and higher efficiency depends upon the relation of surface to bulk of the filament. With a filament in the form of a closely wound helix, where there is a relatively small surface to carry away heat, the gain may be considerable. But with a straight filament of exceedingly small wire there may be only an insignificant gain, and even a loss. In the small "Mazda" lamp of 10 or 20 watts more would be lost than gained by filling the lamp with a gas. In the big units of 300 or 500 watts, very much more is gained than lost by using the gas. The gas-filled lamp represents a compromise based on allowing a big loss by heat conduction and convection by the gas, which is more than compensated by the higher temperature permissible, because the rate of evaporation is kept down by the pressure of the gas.

All kinds of inert gases would not serve the purpose equally well. Other things being equal, obviously the gas having the lesser heat conducting and convecting capacity is the better. Thus nitrogen is much superior to hydrogen, and argon a little better than nitrogen. Therefore, while large lamps may be filled with nitrogen, in the smaller type of gas filled lamps, say, 100-watt lamps, in which nitrogen would result in no appreciable gain, it pays to use argon.

In the gas-filled tungsten lamp, the efficiency is raised from the five watts per candle of the early carbon filament lamp of Edison to two candles per watt, an increase in the ratio of ten to 1, due not only to the gas pressure keeping down the rate of evaporation and permitting a higher operating temperature, as before explained, but further to inherently different characteristics of the two materials, in that a greater proportion of all the vibrations emanating from tungsten, when at the same temperature as carbon, falls within the visible three-quarter octave. The radiations from tungsten in the "Mazda" lamp are thus to some extent favourably selective, compared with the radiations from the carbon filament.

True selective radiation was found out some years ago by Auer von Welsbach and utilised by him in greatly improving gas lighting. In investigating various elements he discovered that the rare oxides of some metals, as thorium and cerium, when heated to incandescence, give out much more light than materials in general, say, for example, carbon or platinum, at the same temperature. When platinum is heated to incandescence in a flame it will emit visible radiations mainly in the yellow part of the spectrum. But place one of these rare oxides in the flame and it will give a greenish-white light much stronger than the light from the platinum, and entirely beyond what would naturally be expected considering the temperature. Thus these materials have the curious property at flame temperatures of producing an abnormal number of vibrations of high frequencies falling within the visible three-quarter octave. Such oxides are in practice formed into a mantle, which is heated by a Bunsen flame, resulting in an increase of lighting efficiency much greater than is obtainable directly from gas. The high efficiency cannot be due to the temperature, because the temperature of a gas mantle is relatively low. The quality of the light corresponds in general to low temperature, and furthermore at no temperature could any merely radiating incandescent body give off just the same quality of light which these materials give. This was the first production of light not directly due to temperature but to some selective radiation, the nature of the materials resulting not in all kinds of vibrations, but more particularly in useful ones.

The question arises, is it possible to gain the same advantage for the incandescent lamp that has been obtained in gas lighting from the Welsbach mantle by using some such selective material for the filament? This has been accomplished to some degree in the "Nernst" incandescent lamp, but the gain was insignificant compared to that obtained with the gas mantle. The reason is this: The temperature of a gas flame is comparatively low, consequently it alone gives little light. But by selective radiation of "luminescence," that is, light not directly dependent upon temperature effect, the added mantle at the same temperature gives, say, ten times as much light, thus increasing the efficiency ten times.

Now in the "Nernst" lamp the temperature is much higher than the gas flame, so that we obtain, say, 20 times as much light as from the gas flame. And since the mantle gives 10 times as much light as the gas flame and the "Nernst" filament gives 20 times as much light as the gas, the increase in efficiency of the "Nernst" lamp, partly due to selective radiation and partly to the higher temperature, is only 50 per cent. So the "Nernst" filament is more efficient than the carbon filament at the same temperature, but the increase is very small compared to the increase in the Welsbach mantle. The percentage of light added by luminescence in the "Nernst" filament is probably the same as that in the mantle, but the filament itself gives so much more light, due to the higher temperature alone, that eventually very little is gained. That is why the "Nernst" lamp did not show such a startling gain over the Welsbach mantle as compared with ordinary gas lighting, and further because it could not be heated to the increased temperature possible in the tantalum lamp and still higher temperature in the later tungsten lamp.

The "Mazda" is much more efficient than the "Nernst" lamp, for while the "Nernst" lamp gains by higher luminescence, the tungsten lamp more than makes up for this by its higher temperature.

The only way to produce real selective vibration, corresponding with the note from the air column in an organ pipe, or from a violin string, is by causing vibration of the atom. But even here we get not a single vibration but a mixture of all the vibrations of which the atom is capable. Therefore it cannot be accomplished by means devised as one would build a piano, by an assemblage of wires of suitable lengths under proper tensions, because there are only a certain number of elements at command, and the atoms must be used as we find them, for we are powerless to modify them or their actions.

Solids and liquids are not available, because their atoms are so close together that they cannot vibrate freely. They may be compared to a heap of sand. While each grain, if separate, could send out its own vibrations and produce a separate colour effect, in the heap all we get is a general sand colour, a mixture of all those kinds of vibrations that are characteristic of sand particles. So a solid or a liquid can give no definite vibration of the spectrum, but only general vibrations of all kind of frequencies, like the incandescent tungsten filament. Only the atoms of gas and vapour give spectrometric light.

Let us see which of the gases and vapours give a large percentage of visible rays. Atoms of the same material, for instance, mercury vapour, will give the same vibrations regardless of whether the temperature is high or low. With higher temperature the intensity will increase, but the frequency remains the same, just as with the violin string, the note is the same whether the string is bowed heavily or lightly, only in the former case the intensity or volume of sound will be greater than in the latter, it will be louder. So with atoms of vapour, whether they be highly heated or not, whether a large or a small current is sent through them, they still keep the same frequency of vibrations, only more or less intense, and thus giving more or less light, although there will also be other vibrations too fast or too slow to come within the visible range.

In order to secure efficient lighting in this way, that is, by luminescence, we should select those chemical elements that happen to have a considerable percentage of their natural vibrations in the visible range. There are practically three of them: mercury, calcium, and titanium. In mercury vapour the green colours predominate, in calcium the orange and red, and in titanium vapour the atomic vibrations have frequencies fairly well distributed over the whole visible range. With any one of them, under favourable conditions, as much as 20 per cent. of the total radiation comes within the visible range, the three-quarter octave, which is several times more than can possibly be obtained from an incandescent body at any temperature, even at the temperature of the sun. There is, therefore, a possibility in this direction of an efficiency in lighting materially higher than is possible with incandescence.

This brings us to the final consideration of the question: what improvements are possible? Take the gas-filled "Mazda" lamp with which two candles per watt are obtained. Possibly the economy may be increased by going to a still higher temperature, close to the melting point of tungsten, and there is still quite a latitude permissible in this direction. It would mean higher gas pressure to keep the evaporation down, and a transparent globe of different composition than at present used because the gas would be very much hotter. Then the loss from heat conduction and convection under the greater gas pressure would be much increased. A better gas for the purpose than nitrogen might be used, perhaps argon. Possibly, an improvement up to three candles per watt could be obtained, but the prospect of any substantial gain is limited.

Another question is: can we find a material, a metal, having a higher melting point than tungsten? Doubtless, it must be an element, because for chemical reasons the melting point of any compound of two materials must lie somewhere between that of either of the materials entering into it. For example, all tungsten compounds have lower melting points than tungsten itself, all carbon compounds have lower melting points than carbon, and so on.

In conclusion, we may hope to increase the efficiency from two candles to three or four candles per watt by incandescence. In the case of the luminous spectrum produced by an electric current flowing through a gas or vapour there is no theoretical limitation because definite rates of vibration result. With the most efficient vapours, those of mercury, calcium, or titanium, we can probably get something like eight to ten candles per watt under favourable conditions, an efficiency much higher than can ever properly be expected from incandescent radiation, but this is under the most favourable laboratory conditions, not as yet at all attainable in any arc lamp in commercial practice. It shows, however—and now we are considering theoretical possibilities—that within the range of luminescent lighting, exemplified in the vacuum tube, and in the luminous arc and flaming arc, there is no theoretical limitation of efficiency, while in incandescent lighting there is a limitation set by the unavoidable production of all kinds of vibration, of which the useful embrace only three-quarters of an octave. By luminescence we may, as already stated, probably attain an efficiency of eight candles per watt, but should some new way of producing luminescence be discovered by which all the vibrations would have a frequency, say, between four hundred and six hundred millions of millions of cycles per second, about 50 candles per watt would be obtained. This can be done, because the firefly does it, but we do not yet know how he does it.

NOTES ON LOCOMOTIVE BOILERS.

WHEN a newly designed boiler for a locomotive is being built in the shops, considerable speculation will doubtless develop among those interested in its construction as to the probable effects of working conditions on it, especially if any departure from what may be termed orthodox details has been made. The regular examination necessary during service will be closely watched, and when the boiler first comes to the shops for overhaul and repair its condition will be very critically enquired into. A very considerable volume might be devoted to the opinions of experts in boilermaking on the different boilers which have been constructed under their supervision or of those in their charge, and similarly much could be heard of the special treatment necessary for the peculiarities in details requiring their attention.

Treating of generalities, the local effects of the great variations in temperature to which a boiler and its firebox are subjected affect very intimately its life; the treatment a boiler is accorded will also influence this. Further, to go into details, the water which, when used alone, is quite harmless, may become dangerous in its action when mixed with other supplies. The result may be corrosion of the plates and eating away of the metal over large areas, or it may give rise to "pitting" in more closely defined areas. With some water the impurities deposited from it form a scale which acts as a hard protecting "shell" over the internal parts of the boiler; with others the earthy matter held in suspension is thrown down as sediment in the form of mud. In either case, if the deposit is allowed to accumulate, it may act as a preventive against the water having free access to the plates, with the consequence that they will be overheated by fire and suffer accordingly. Water spaces of restricted area will get blocked up with these deposits, preventing the circulation of water and reducing the efficiency of the boiler.

The frequent changes of temperature to which a boiler is subjected cause constant movement of the different parts forming it, and there is in consequence a continual variation in length, &c., of the various plates. This continual movement is often known as the "breathing" of the boiler. It is quite impossible to prevent it, and therefore it should be allowed for. As some parts move more than others, and at varying times, a "hingeing" action occurs in places, and as this is often concentrated at points close to where a rigid part is attached to something less solid, it is here where "grooving" will be expected to take place.

The "groove" made is a more or less continuous line of deep furrows close together, probably caused by the continual movement due to varying temperature. This latter causes the protecting scale to be dislodged, and, allowing the fresh "naked" plate to be exposed to the action of the water, the plate is thus rusted or eaten away at these points. This action seldom takes place above the water level or in the steam space

of the boiler; in some parts the effect is very severe, as, for instance, round the outer firebox casing plate, level with the top of the foundation ring, where the groove will, if the plate is allowed to remain, eat right through.

As the defect above mentioned occurs inside the boiler, and often in parts that are inaccessible and difficult even to be seen, the examination of a boiler has to be much more than a mere cursory glance which may be sufficient to enable an engine examiner to detect at once any serious defect in the engine or running gear, which is usually in the open and accessible.

The outside of the boiler is also subject to the action of the atmosphere, causing rust to form on the plates, &c., gradually corroding them away. The "clothing" covers most of these parts up, and the removal of the lagging plates and asbestos or other non-conducting covering is necessary from time to time, in order to enable the condition of the boiler plate to be ascertained. The outside of the boiler should be coated with a thick oxide paint before the lagging is put on, but as a rule this paint does not last very long, and thus the plates are gradually exposed to rust.

The interior fireboxes need careful watching to avoid risks due to wasting away of the plates and stay-heads from the action of the fire. The rapid rate at which the fuel is burned on the grate, and the violent movement of the fire in the firebox, due to the biting action of the blast, has its effect in the wear of the plates by the attrition of the sharp particles of fuel upon the metal; especially is this the case at a point from 12in. to 18in. above the firebox level, where the action is most severely felt. The cutting action of the flame along the lower side of the brick arch wastes the plate away here, and this effect is seen to be most severe at the end of the arch where the flame turns to pass over the arch on its way to the tubes.

The more rapidly the fire is made to burn and a boiler forced—or, in other words, the harder the engine is worked—the quicker the firebox will be worn out. If careful observations are taken, it will be found, in all probability, that there is a very close relationship between the amount of copper worn or wasted away from the firebox by the action of the fire, and the quantity of fuel burned upon the firebars in a given time. The actual period of time that elapses between the making and the renewal of a firebox is, no doubt, of less moment in this connection than the quantity of fuel burnt and the work done by the engine in the time. When examining the firebox, the thickness can be gauged, as a rough guide, by tapping it with a hammer. In case of doubt, a small hole should be drilled through the plate, and the actual thickness measured by inserting a hook-ended gauge in the hole.

The mouthpiece or plate of the inner firebox that encircles the firehole is another part that wears out more rapidly than the body of the box; especially is this so at the lower part of the firehole. This wearing, or rather burning, away of the metal here is due to the fact that there is no water at the opposite side of it to conduct away the heat and keep the place cool. The mass of metal forming the firehole ring not only keeps the water away from the plate there, but also gets extremely hot and allows the plate to be burnt away.

The stay-heads are liable to be abraded off by the action of the fire, and must be examined and defective ones renewed before they are reduced too much for safety. Unskilful firing, with sudden changes of temperature, owing to cold air entering through the firehole when the door is open for too long a period while the boiler is hot, causes stays to give trouble. Further, the dirt collects on the water side of the plates, and prevents the heat from passing freely to the water. In stubborn cases of dirt or scale thus forming, it may even be necessary to cut out some of the stays to enable the dirt to be dislodged from the water space.

From the foregoing remarks it will be realised that the charge of boilers is a post which carries with it the need of constant watchful care, if trouble from failure is to be avoided, and especially is this so in these days of hurry, when the boilers are forced so much, and consequently wear out much quicker than was the case in the days of low steam pressure, when engines were "nursed" more. With the foregoing remarks regarding the work a boiler has to undergo in service, the problems which beset the builder will be better understood when he sets out to do the work of laying-out the plates, forming them to shape, and gradually assembles all the pieces that go to make up the complete boiler.

From the dimensions given on the drawings, the plates will have to be ordered; it is not usual for the shops where the boilers are built also to manufacture the plates. These are, therefore, ordered from a reputable firm who make a speciality of this kind of work. The locomotive superintendent gives the specification for the material and tests that he requires the plates to undergo before they are delivered, and usually he also requires an allowance on the size of each plate delivered, which can be cut off and tested after receipt of the plates. As each plate is marked when the test pieces are cut off, it can be realised that every plate used in a boiler has its record, so that in case of failure afterwards the results of the tests on every plate can be found, and proof given that only the best material was used in the construction of the boiler.

Owing to the fact that boilers nowadays wear out very quickly; and therefore have to be fairly frequently replaced, it follows that speed and cheapness in constructing them are important factors in their manufacture. Therefore the use of machinery in doing as much as possible of the work is the rule, and as a result many machine-making firms have specialised in designing and building machines for the use of boilermakers. Great strength and simplicity of design are features that this class of machine must have, as the work they will be called on to do is very arduous.

One of the operations performed by machines is levelling the plates after arrival, as they often get bent and buckled in transit from the makers. After "marking off," they are sheared to rough size, and the rivet holes punched or drilled, the edges planed to exact size, and the manholes and other large circular parts cut on a boring mill. Some of the plates have to be rolled to shape for the barrel, and some heated and flanged for those parts that need this treatment, such as front and back ends of the boiler, throat plate, dome, &c. When the boiler is put together, bolts are put through some of the rivet holes to hold the plates together, and when the whole has been tried over, the rivets are closed by hydraulic riveters. Pneumatic machines may be used for some parts where it is found most convenient to employ them.

The edges of all the plates must be caulked, preferably by pneumatic caulkers, and the inner firebox is then put in. The stay-holes are drilled, if they have not been done before the plates are assembled together, and tapped. Machines with large arms are used for tapping the stay-holes if portable pneumatic or electric driven machines are not available. The stays are put in and riveted over by hand or machine.

From the above brief list of the machine operations it will be realised what a large proportion of the work is done mechanically, and how the work of production is "speeded up" in the modern boilership.—"The Locomotive."

INFLUENCE OF PRESSURE ON EXPLOSIBILITY OF ACETYLENE.

THE influence of pressure on the explosibility of acetylene, as investigated by the U.S. Bureau of Mines, is given in the Bureau's Technical Paper No. 112, prepared by George A. Burrell and G. G. Oberfell from experiments made to determine the limits of complete propagation of flame in mixtures of acetylene and air. Acetylene, not mixed with air, was enclosed in over mercury in a 100 c.c. glass vessel, and its pressure slowly increased by means of a column of mercury until a maximum pressure of five atmospheres was obtained. There was no explosion. The experiment was twice repeated, and each time under a pressure of five atmospheres a mild explosion with the formation of much carbon resulted when a platinum coil in the gas was electrically brought to a white heat, while with the spark from an induction coil there was a violent explosion at three atmospheres. When acetylene was mixed with air so as to form 10, 20, 30, 40, 50, 60, 70, 80, and 90 per cent. acetylene mixtures, there was no explosion from compressing the mixtures to one, two, three, four, and five atmospheres. There was no use of any means of ignition such as an electric spark or a heated platinum coil. The experiments showed that the smallest proportion of acetylene capable of propagating a flame in a mixture of acetylene and air was 2·53 per cent.; the largest was about 73.

THE DESIGN OF HIGH-PRESSURE DISTRIBUTION SYSTEMS.*

BY J. R. BEARD, M.SC.

(*Concluded from page 112.*)

II. (*b*). **The Lay-out of the Distribution System.**—Except in special circumstances it is usually essential for each sub-station to have at least two separate sources of supply, and, if the supply to the sub-station is not to be interrupted by a failure of one source, some form of discriminating protective device must be installed on each feeder in order to isolate it automatically in the event of its breakdown. It is, however, not so generally recognised that it is of equal importance that a fault on one feeder must not interfere with the supply through the sound feeders however severe the fault may be. The only forms of protection in commercial use which meet these conditions under all circumstances are the balanced-current protective system with pilot wires and the split-conductor protective system. Both have the further advantage that the isolation of the faulty feeder is practically instantaneous and can be effected with quite a low value of the fault current so that the disturbance to the general system is a minimum. Full particulars of these protective systems and of their advantages are given in Mr. Wedmore's recent paper, the split-conductor system being finally recommended as the more suitable for feeder protection.

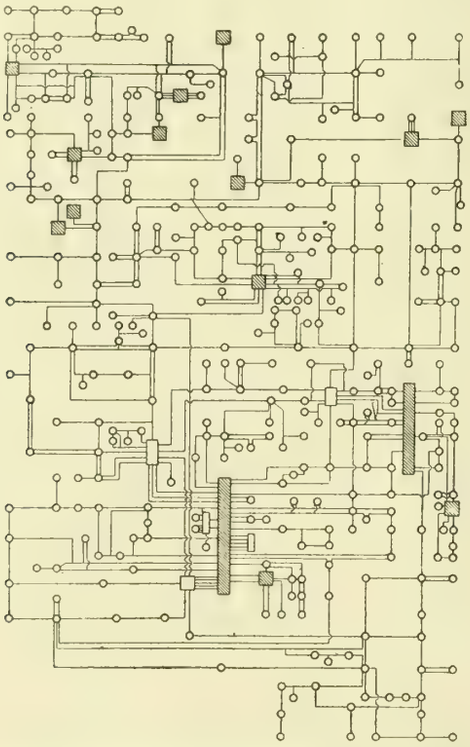


FIG. 8.—NORTH-EAST COAST HIGH-PRESSURE DISTRIBUTION SYSTEM.
NOTE.—Generating stations shown cross-hatched.

It is probable that one or other of them would be universally used if it were not that there is often an impression that they involve extra capital cost which is not justified by the extra security they give. Undoubtedly they increase the cost per mile of a main of given section, but this is counterbalanced by the saving effected by the possibility of using an interconnected system which allows of: (*a*) A reduction in the cost of mains due to the saving in spare feeders. (*b*) A reduction in the cost of mains due to the possibility of replacing a number of small feeders by a few large ones which are cheaper per ampere of carrying capacity. (*c*) A reduction in the amount of switchgear required. (*d*) A reduction in the total annual cost of mains, owing to it being possible to take advantage of the diversity between the demands of different sub-stations.

The extent to which a system may be safely interconnected by the use of these devices is shown by Fig. 8, which illustrates diagrammatically the high-pressure distribution system on the North-east Coast. No less than 350 sub-stations are connected to this system, and it is fed by 15 power stations, many of which utilise waste energy in the form of exhaust steam and coke-oven gas. The whole of the feeders shown are normally in commission and interconnected, the older ones being equipped with balanced-current protection and the more recent ones with split-conductor protection. As showing the reliability of both these forms of protection the operating records of this system show that over a period of time, selected quite at random, faults occurred on 23 feeders equipped with automatic protection, and that in 22 cases the faulty feeder was instantaneously isolated without causing an interruption of supply to a single sub-station except in one instance where the sub-station in question was given a non-duplicate supply through the faulty feeder. In the remaining case, although the protective gear operated satisfactorily, one of the feeder switches failed to open due to a mechanical fault; this was equivalent to a bus-bar fault and brought out the overload gear at two sectioning points, thus limiting the trouble to this section of the system.

In the following investigation an attempt is made to give definite figures for the saving effected by an interconnected system. These figures show that the saving is not only sufficient to balance the cost of the special protective devices, but that a system so equipped is actually cheaper than systems protected by less efficient methods which do not give the same freedom from interruption of supply.

In order that the results may be on the conservative side the extra cost of the special protective devices has been taken at 10 per cent. on the switchgear, including building accommodation, and at two shillings per yard on the mains, which is sufficient to cover the cost of balanced-current protection and decidedly more than sufficient to cover the cost of split-conductor protection. In the first place, a comparison will be made between the three types of system that are available in the case of the supply to a number of sub-stations the supply to which must be reasonably free from interruption. These are:—

(1) An interconnected system equipped with balanced-current or split-conductor protection, which ensures complete continuity of supply to all sub-stations in the event of a fault on a feeder.

(2) A simple radial system with duplicate feeders direct from the power station to each sub-station, equipped with time-limit overloads at the power-station end and reverse-power relays at the sub-station end. This limits the risk of interruption to the sub-station fed by the faulty feeder and has been adopted for important supplies such as that to the London Underground Railways. Owing to the defects of the reverse-power relay it cannot ensure complete continuity of supply to the sub-station affected.

(3) A series radial system with duplicate feeders to each sub-station protected as in (2), but with direct feeders from the power station to only half the sub-stations, each of these in turn feeding one of the remaining sub-stations. This involves graded overload gear, and a faulty feeder may shut down both the sub-stations in connection with it and will probably shut down one of them; it is therefore only permissible where continuity of supply is not of such vital importance.

For the purpose of the comparison a typical case is assumed of an area of 25 square miles with the power station at the centre and a sub-station with a maximum load of 500 kw. at 0·8 power factor and a load factor of 30 per cent. situated at the centre of each square mile, the distribution being effected by underground mains at 6,000 volts. It is assumed that owing to the diversity between the various sub-station loads the power-station load-factor will be 50 per cent., and the average feeder load-factor on an interconnected system 40 per cent. The average maximum feeder currents are therefore deduced by assuming the sub-station maximum demand to be reduced in the ratio of the sub-station load-factor to the average feeder load-factor. This only holds for the interconnected system, but in the first instance the same reduced sub-station demands will be taken for other types of system, *i.e.*, the advantage which an interconnected system gains from its utilisation of diversity is neglected.

The annual cost per switch panel is taken from Fig. 12, and the annual cost of the mains from Fig. 7, the proper deductions being made in the case of types (2) and (3) for the omission of the special protective devices. Table I. gives the comparison, while the diagrammatic lay-outs of the three types of system are shown in Fig. 9 (*a*), (*b*), and (*c*).

* Paper read before the Institution of Electrical Engineers.

In certain cases where momentary interruption of supply is not of great importance a "tee" system has been used, arranged as shown in Fig. 9 (*d*). Each sub-station is normally given a non-duplicate supply from one of the feeders, and arrangements are made for the sub-station to be changed over to the other feeder in emergency, thus involving a complete temporary interruption in the supply to all the sub-stations fed by the faulty feeder. In a modification of this system both tees into the sub-station are normally closed through switches equipped with time-limit gear, but the sub-station bus-bars are sectioned by a special switch. The sectioning switch may be either left open or it may be closed and equipped with instantaneous overload gear so that it will immediately trip in case of a feeder fault. In either case supply is automatically maintained to half the sub-station bus-bars, and by opening the faulty feeder switch and closing the sectioning switch complete supply to the sub-station can be resumed.

TABLE I.

Type of system.	Reference to Figs.	Number of switches	Mileage of mains.	Annual costs. £	Percentage increased cost over interconnected system.
Interconnected ..	9 (*a*)	64	32·0	4,752	—
Simple radial	9 (*b*)	96	93·7	7,664	61·3
Series radial	9 (*c*)	96	61·2	6,075	27·8

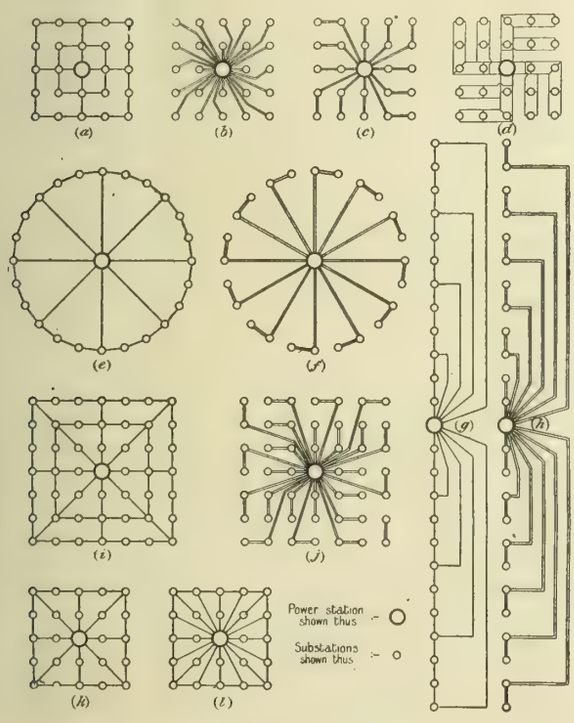


FIG. 9.—DIAGRAMMATIC LAY-OUTS OF DISTRIBUTION SYSTEMS.

Table II. gives a comparison of these systems with the interconnected system, and it is interesting to note that the latter is still cheaper in spite of the great sacrifices in security entailed by the "tee" systems.

TABLE II.

Type of system.	Reference to Figs.	Number of switches	Mileage of mains.	Annual costs. £	Percentage increased cost over interconnected system.
Interconnected	9 (*a*)	64	32·0	4,752	—
Semi-duplicate "tee"	9 (*d*)	80	48·0	5,478	15·3
Change-over "tee"	9 (*d*)	56	48·0	5,216	9·8

The foregoing comparison proves that the interconnected system is the most economical for the particular case which has been selected as typical; but in order to make the investigation complete it is necessary to show that this superiority still holds under other conditions, and accordingly the interconnected system will be compared with the cheapest system giving reasonable security of supply—the series radial system under various modified conditions which may obtain in practice. These are:—

(1) The same number of sub-stations distributed one mile apart in a ring round the power station, or in line one mile apart with the power station at the centre, as shown in Fig. 9 (*e*), (*f*), (*g*), and (*h*).

(2) The area of supply extended or decreased with the same number of sub-stations and the same total load on the system, *i.e.*, the sub-stations situated at the increased and decreased spacings of one per 4 square miles and four per square mile respectively, instead of one per square mile, the load per sub-station remaining the same.

TABLE III.

Nature of modification to the typical system.	Type of system.	Reference to Fig. 9.	No. of switches.	Mileage of mains.	Annual cost. £.	Percentage increased cost over corresponding interconnected system.
Sub-stations distributed in ring.	Interconnected	(*e*)	64	54·6	8,179	—
	Series radial	(*f*)	96	115·9	10,977	34·2
Sub-stations distributed in line.	Interconnected	(*g*)	66	84	11,508	—
	Series radial	(*h*)	96	168	15,644	35·9
Sub-stations spaced one per 4 square miles.	Interconnected	(*a*)	64	64·0	8,736	—
	Series radial	(*c*)	96	122·4	11,103	27·1
Sub-stations spaced four per square mile.	Interconnected	(*a*)	64	16·0	2,760	—
	Series radial	(*c*)	96	30·6	3,562	29·0
Area of supply increased to 49 square miles.	Interconnected	(*i*)	128	69·0	11,108	—
	Series radial	(*j*)	192	166·9	16,135	45·2
Area of supply increased to 81 square miles.	Interconnected	—	192	120·8	20,521	—
	Series radial	—	320	347·7	33,124	61·4
Sub-station load reduced to 250 kilowatts.	Interconnected	(*a*)	64	32·0	3,960	—
	Series radial	(*c*)	96	61·2	5,295	33·7
Sub-station load increased to 1,000 kilowatts.	Interconnected	(*k*)	64	35·3	6,533	—
	Series radial	(*c*)	96	61·2	7,721	18·2
Sub-station load increased to 2,000 kilowatts.	Interconnected	(*l*)	80	53·2	10,469	—
	Series radial	(*c*)	96	61·2	10,572	1·0

(3) The area of supply extended to, say, 49 square miles with the same density of load and a correspondingly increased number of sub-stations supplied from the central power station, as shown in Fig. 9 (*i*) and (*j*). A further extension of the area of supply to 81 square miles has also been worked out, but it has not been considered necessary to complicate Fig. 9 with details of this, as the lay-outs are similar to those for the 49 square miles. There is no need to consider a reduction in the area of supply as this is already quite small.

(4) The original distribution of sub-stations but with increased or reduced loads per sub-station, the alternative loads considered being 250 kw., 1,000 kw., and 2,000 kw. The arrangement of feeders remains the same for the series radial system, as a cable capable of dealing with the load of two 2,000 kw. sub-stations in emergency is not too large to be handled. For the interconnected system it is necessary to run more feeders from the power station to deal with the heavier loads, the feeder arrangements which would be adopted for the 1,000 kw. and 2,000 kw. sub-stations being shown in Fig. 9 (*k*) and (*l*) respectively.

The details of the comparison are given in Table III. The outstanding features of this comparison are: (*a*) The economy of the interconnected system is generally maintained. (*b*) The saving effected by an interconnected system rapidly increases as the area of supply is enlarged. This is important as only relatively restricted areas have been considered. (*c*) The saving is greatest for lightly-loaded sub-stations and decreases as the sub-station loading increases. In the case of the most

heavily loaded sub-station it would appear at a first glance that while the interconnected system may have other advantages its direct economy is very small. This is only apparent, for in the first case the saving due to diversity has been ignored, and secondly it will be found on investigation that a point has been reached at which distribution at so low a voltage as 6,000 is uneconomical. The question of the most economical distribution voltage will be considered further at a later stage, but it may be noted now that with a sub-station

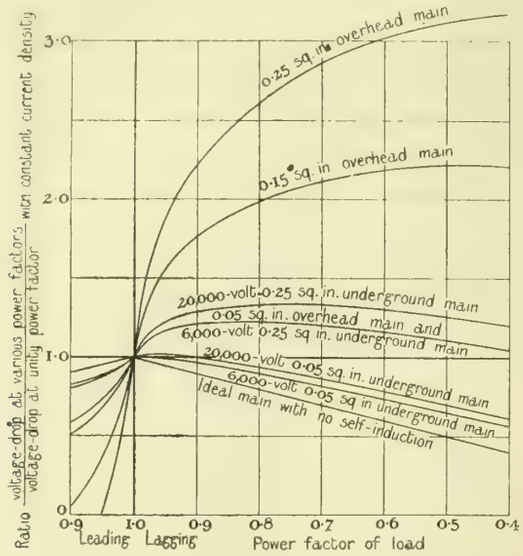


FIG. 10.—EFFECT OF INDUCTIVE DROP AT DIFFERENT POWER FACTORS FOR VARIOUS MAINS.

loading as high as 2,000 kw. the distribution system costs 37·1 per cent. more at 6,000 volts than it would at 11,000 volts, while if a pressure of 11,000 volts were adopted the interconnected system would show a saving of 21·8 per cent. compared with a series radial system at the same voltage.

The possible further savings which may be effected if diversity is taken into account have been considered, and without going into details of the calculation it may be taken as adding something of the order of 4½ per cent. to the cost of a simple radial system, and rather less to the cost of a series radial system.

When comparing an interconnected system with other types, two further points must also be borne in mind. (1) It is a very difficult matter exactly to forecast sub-station maximum loads or, as in the case of railways, definitely to fix the allocation between the various sub-stations. If the sub-stations are fed independently it is obvious that in proportioning feeders to them allowance must be made for the assumed maximum loads being exceeded or varied, while if the sub-stations are interconnected the particular distribution between the sub-stations does not greatly matter so long as the total system load is unaltered. (2) The greater part of the saving effected by an interconnected system is in the trunk feeders, and in consequence it is more marked the farther the power stations are removed from the centres of load. In the above comparisons the power station has been taken at the electrical centre of gravity of the load and therefore at the least favourable position for the interconnected system.

So far the investigation has been limited to the comparatively low voltage of 6,000; but, speaking generally, the higher the system voltage the greater is the economy to be obtained by interconnection. This is obvious if it is remembered that:—

(*a*) The higher the voltage the less is the proportionate cost of the protective devices, which is practically independent of the voltage.

(*b*) The higher the voltage the smaller is the section of the mains for given loads, and consequently the greater the advantage offered by interconnection in reducing the total length of mains and increasing their average capacity.

This is shown very clearly by Table IV., which gives the comparison at various distribution voltages between the annual costs of interconnected and series radial systems for the typical distribution of sub-stations and a load of 2,000 kw. per sub station.

II. (*c*) **The Most Suitable Distribution Voltage.**—In settling the distribution voltage the primary consideration is that it shall be sufficiently high to ensure that the voltage variation at the boundaries of the supply area can be kept within a reasonable amount without putting an excessive amount of copper in the feeders. It is usually desirable that the voltage variation should not exceed 5 per cent. either side of the normal, *i.e.*, a total of 10 per cent., and from this about 2½ per

TABLE IV.

Distribution voltage.	Interconnected system.		Series-radial system.		Percentage increased cost of series radial system corresponding interconnected system.
	Reference to Fig. 9.	Annual cost. £.	Reference to Fig. 9.	Annual cost. £.	
6,000	(*l*)	10,469	(*c*)	10,572	1·0
11,000	(*k*)	7,634	(*c*)	9,295	21·8
20,000	(*a*)	7,984	(*c*)	10,756	34·8

cent. should be deducted for transformer voltage-drop, leaving a permissible maximum drop of 7½ per cent. in the high-pressure mains. Fig. 6 shows that under the same conditions the current density in the mains, and therefore the resistance voltage-drop per mile, is approximately independent of their section. The actual figures taken from Fig. 6 are given in Table V.

TABLE V.

Type of main.	Amperes per square inch at maximum load.		Resistance voltage-drop between phases per mile at maximum load.	
	With the economical loading.	With decreased loading corresponding to 5 per cent. extra cost.	With the economical loading.	With decreased loading corresponding to 5 per cent. extra cost.
Underground mains up to 11,000 volts	910	635	68·1	47·5
20,000-volt underground mains	1,190	800	88·8	59·9
Overhead mains up to 20,000 volts	800	540	59·9	40·4

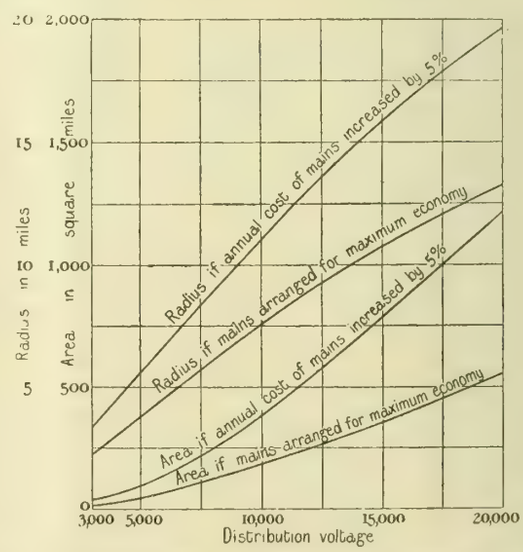


FIG. 11.—RADIUS AND AREA OF DISTRIBUTION AT VARIOUS VOLTAGES.

Permissible drop, 7½ per cent. Frequency, 50 cycles. Average power factor, 0·8. Equal lengths of underground and overhead mains.

As the power factor of most distribution systems is less than unity it is also necessary to take account of the inductive voltage-drop. This is not independent of the section, but given the current density from Table V. and the frequency of the system it can be readily calculated from the size and spacing of the conductors. Fig. 10 shows, for several typical sizes of both underground and overhead mains at various voltages, the relative amount by which the inductive drop increases the total voltage-drop at various power factors. The

calculations are based on a frequency of 50 cycles per second and on a constant current density, since the economical value for the latter is independent of the power factor. They also assume the use of ordinary 3-conductor mains; if arranged for split-conductor protection the inductive drop would be appreciably reduced.

Table VI.

System voltage actually adopted	5,500	20,000
Number of switches per mile of main	2·63	0·725
Average maximum kilovolt-amperes per mile of main	450	3,500
Most economical system voltage	5,700	16,000
Upper and lower limits for system voltages with 5 per cent. extra cost of distribution system	9,500	20,000
	3,200	12,000

It is evident that the maximum radius of distribution and area of supply at a given voltage will vary according to the power factor of the system and to the various factors which determine the inductive drop, but in order to give an approximate idea of the relative figures for the maximum radius and area at various voltages the curves given in Fig. 11 have been prepared on the following assumptions: (1) Permissible voltage drop 7·5 per cent. (2) Average power factor 0·8. (3) A network comprising equal lengths of underground and overhead mains. (4) An average cross-section of main of 0·15 sq. in. (5) A frequency of 50.

It is interesting to note that, although it is more economical to run higher voltage cable at an increased current density, the curves of both area and radius have still a steep upward tendency at 20,000 volts. This would be further accentuated if allowance were made for the fact that the average cross-

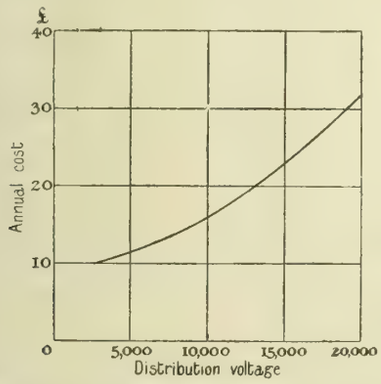


Fig. 12.—Annual Cost of Switchgear per Panel.

section of main tends to decrease at higher voltages, with a corresponding decrease in the value of the inductive drop relative to the resistance drop.

It is, however, not sufficient to settle the distribution voltage on the basis of permissible voltage-drop alone. It is also important to choose that voltage which gives the cheapest distribution system, and from this point of view it may often pay to use a voltage much higher than that which is required by the conditions of voltage-drop. Generally speaking, the higher the loads which have to be dealt with the higher is the economical voltage; but it is also necessary to take into consideration the proportion between the total number of switches required and the total mileage of mains, as the cost of switchgear increases with the voltage. Fig. 12 gives fairly safe figures for the annual cost per switch at different voltages on the basis of annual charges of 8 per cent. on the switchgear and the corresponding building accommodation, and these figures have been used in the following investigation.

Taking a system comprising 24 sub-stations evenly spaced as in Fig. 9 (*a*), and allowing an average of 2½ switches per sub-station for controlling the step-down transformers, the total annual cost of switchgear and mains has been calculated for various distribution voltages and various sub-station loadings. In addition the spacing of the sub-stations has also been varied so as to give several comparative proportions between the number of switches and the mileage of mains. From these results the series of curves given in Fig. 13a have been plotted showing the most economical voltage under the varying conditions.

It will be seen by reference to Fig. 7 that the annual costs of mains of varying sections lie approximately on straight lines, and it is therefore permissible, by plotting the curves in Fig. 13a to a base of average demands, to make the results applicable to any arrangement of network whatever its type or extent. In order to find the most economical voltage for a given distribution of loads, the procedure would then be to

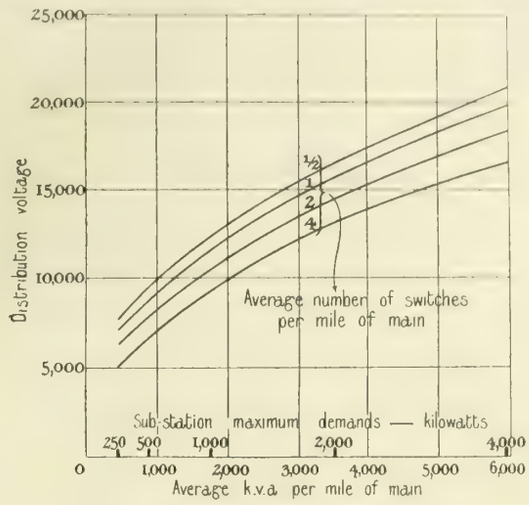


Fig. 13a.—Economical Distribution Voltage.

assume a voltage which it is anticipated will be about correct, to lay out the distribution system on this basis, calculate from this the average number of kilovolt-amperes per mile of main and the number of switches per mile of main, and then from these two figures find from the curves in Fig. 13a what the most economical voltage would be. If the original voltage which had been assumed should prove to have been so incorrect that the arrangement of feeders and the number of switches would be appreciably altered by the adoption of the revised voltage, it may be desirable to lay out the system afresh with the revised voltage and afterwards check the results again with the curves in Fig. 13a, the method being thus one of trial and error. As a rule, however, the first voltage assumed should be sufficiently close to the correct figure to enable the latter to be obtained by the first trial. The economical voltage obtained in this way must of course be always checked to ensure that it also meets the requirements of voltage-drop.

In order to give some idea of the extent to which the economical voltage can be departed from, the curves given in Fig. 13b have also been calculated; these show the upper and lower limits of voltage corresponding to an increase of 5 per cent. in the cost of the distribution system. The limits are fairly wide, but, if they are exceeded, the extra cost of the

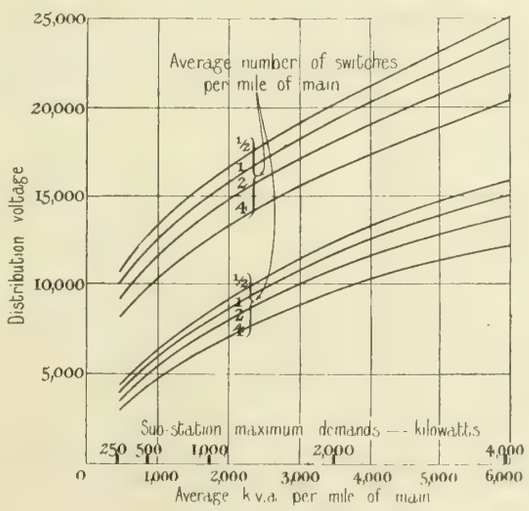


Fig. 13b.—Upper and Lower Limits of Distribution Voltage for 5 per Cent. Increased Cost of Distribution System.

distribution system increases at a cumulatively rapid rate. In practice it is advisable to adopt a voltage in the neighbourhood of the upper limit in order to keep down the voltage-drop as much as possible, and also in order to make allowance for the increase in the density of load which will usually occur.

As might be expected, Fig. 13 shows that the heavier the loads to be supplied and the more they are concentrated the

higher is the most economical voltage. It should be noticed that the curves show no signs that at 20,000 volts the maximum economical voltage has been reached, provided the system loading is heavy enough, and hence for the larger systems of the future we may expect that for economical reasons alone the distribution voltage will be raised above 20,000 volts.

These calculations only refer to underground mains; with overhead mains the economical voltage will be higher, since there is so little difference between their cost at various voltages.

In order to see what are typical figures in actual practice for the number of switches per mile of main and the average number of kilovolt-amperes per mile of main, the accompanying table has been prepared for two typical systems for which the author has had access to the necessary data, and as a matter of interest the corresponding economical and limiting values for the distribution voltage have been deduced from Fig. 13.

Conclusion.—So many factors are involved that it has only been possible to attempt a general survey of the problem of high-pressure distribution, but it is hoped that this may prove useful as a starting point in the detailed consideration of any particular case.

Theoretical calculations must, however, be used with caution. The results of the graph and the slide rule should always be considered in conjunction with the results of practical experience and the whole sifted by the exercise of judgment, accuracy in which is the true test of an engineer. The following paragraph in Prof. Arthur Schuster's address to the British Association is so pertinent to the subject that perhaps its quotation may be permitted:—

"Why does a theory ever fail, though it may be sound in reasoning? It can only do so because every problem involves a much larger number of conditions than those which the investigator can take into account. He therefore rejects those which he believes to be un-essential, and if his judgment is at fault he goes wrong. But the practical man will often fail for the same reason. When not supported by theoretical knowledge he generalises the result of an observation or experiment, applying it to cases where the result is determined by an altogether different set of conditions. To be infallible the theorist would have to take account of an infinite number of circumstances and his calculations would become unmanageable, while the experimenter would have to perform an infinite number of experiments, and both would only be able to draw correct conclusions after an infinite lapse of time. They have to trust their intuition in selecting what can be omitted with impunity, and if they fail, it is mainly due to the same defect of judgment. And so it is in all professions: failure results from the omission of essential considerations which change the venue of the problem."

In conclusion, the author wishes to record his obligations to the Newcastle-upon-Tyne Electric Supply Company, Ltd., and associated power companies on the North-east Coast, and to their consulting engineers, Messrs. Merz & McLellan, for permission to use much of the data on which the conclusions of the paper are based.

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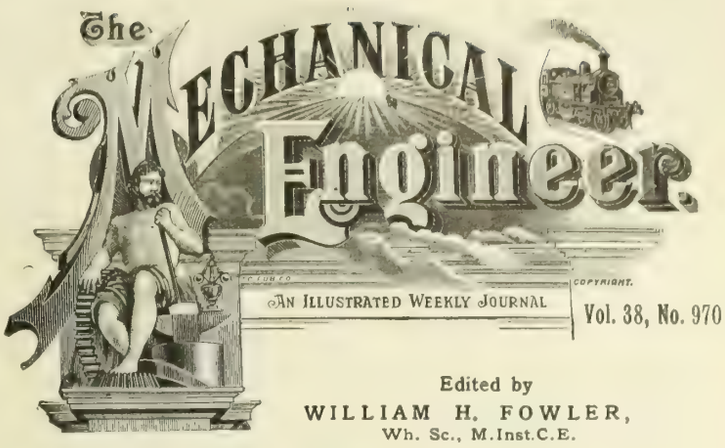

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Industrial Diseases of Iron and Steel Workers.

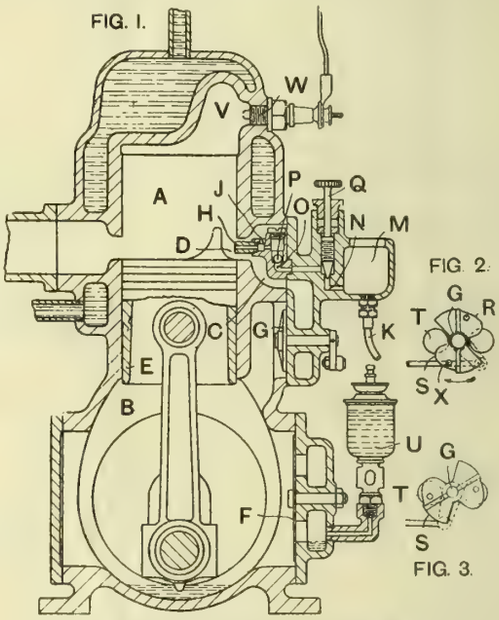
It is often erroneously assumed that the working conditions in a coal pit are more inimical to health and longevity than almost any other trade. That the work is grimy and arduous goes without saying, but statistics show that taking into account the daily toll of minor accidents, and the occasional calamities from explosion that stun the public by their magnitude, the average length of life of coal miners compares very favourably with those engaged in the manufacture of iron and steel. There are seldom any sensational calamities to record, but the insidious action of diseases of the heart and lungs are greatly accentuated, and in the aggregate produce more disastrous results. At every stage of life, says the Registrar-General in his annual report, the death rate amongst iron and steel workers exceeds the average for metal workers generally in the main working period of life (viz., from 25 to 65 years) by 18 per cent. Dr. J. W. Edwards, of Middlesbro', in an address to the British Medical Association, made the subject, which is of special importance to that centre of iron and steel industry, a matter of analysis, and the results of his researches are instructive. Briefly, the primary causes of the excessive mortality are the working in high temperatures with alternate exposure to cold currents of air, and of fiery suffocating gases, coupled with the inhalation of dust, excessive fatigue, careless habits, bad housing, and intemperance in food and drink. Of the latter especially he has some pertinent remarks which it is to be feared, however, so far as the workers themselves are concerned, will fall like seed on stony ground, so engrained do personal habits become and so difficult are the prejudices of ignorance to surmount. There is an inveterate belief that for hard physical work a large consumption of animal food is necessary. That a greater quantity may be advantageous where meal times are limited may be admitted, but the best

authorities are agreed that animal food, under our climatic conditions, is not so imperative as many workmen think. The enormous increase in its consumption is a phenomenon of the present generation, and the gain, as Dr. Edwards remarks, problematic. Natives of many other countries perform prodigious tasks on a diet into which meat scarcely enters, and the popular notion that health and strength are in proportion to the amount of beef a man consumes, especially when washed down with beer, is quite wrong. The immediate results, as medical men know only too well, are dyspepsia, lassitude of the animal organs, and eventually chronic disease. It is difficult to touch upon the drink question without seeming to be prejudiced, so closely linked with it are traditional beliefs, inherited craving, personal tastes, and habit. To a large section of workmen it is an article of faith, unfortunately, that beer is necessary for their well-being, and that nothing can take its place. The daily experience of physicians and surgeons on the contrary shows that owing to alcoholic habits diseases frequently run a long course instead of a short one, and that often recovery does not take place at all counts for little in overcoming the prejudice. The physiological fact remains, however, that alcohol impairs resistance to disease as well as mental and physical efficiency, and the more iron and steel workers can be made to realise this the better for their welfare. Alcohol, of course, is not the only predisposing cause to ill-health. Bad housing is another large factor. It is not uncommon for families of five or six persons to be housed in a cottage with four or five poky rooms, none of which contain adequate breathing space, and it is not surprising that with a cramped outlook on life men coming off duty tired, cold, and hungry, and little to attract them to their comfortless home, turn into the brilliantly-lighted public-house on their way, where companionship and alcoholic stimulants lead them to stay often in damp working clothes for hours after they should have been changed, and the body refreshed with wholesome food. It is little wonder then that tissues are ill-repaired, nerves little refreshed, and that repetition of the same dull round impairs the powers of resistance to the diseases ever ready to pounce on the enfeebled or the careless who ignore the risks attending sudden chills, poisonous gases, unsuitable food, or excessive indulgence in alcohol. A contemplation of the above suggests many directions in which reforms are possible. Personal errors in eating and drinking are largely the products of ignorance and can only be combated by persistent educational effort, and the fact that the results of this are often so slow as to appear almost imperceptible should not deter its exercise. Much, however, can be done to make the lot of the worker both during his daily toil and in his intervals for repose more enjoyable. Many employers are providing greater conveniences for cleanliness and recreation in the shape of baths, social clubs, and suitable provision for meals. The Munitions department has set a praiseworthy example in this direction, and the lead will, doubtless, be more extensively followed. Everything which tends to increase the workman's self-respect and contentment is an incentive to good health, and to that extent a valuable national asset worth striving and paying for.

PETTER'S TWO-CYCLE OIL ENGINE.

THE accompanying illustrations show a design of 2-cycle internal-combustion engine, the invention of Mr. E. W. Petter, Nautilus Works, Yeovil, Somerset, of the kind in which air is compressed in the crank case of the engine by the downward thrust of the piston, a portion of the compressed air being conducted to the cylinder and there utilised to support combustion, the other portion being employed to force the fuel that has been drawn into the nozzle from the fuel chamber during the suction period of the crank-chamber cycle, into the cylinder at the same time as the inlet port is uncovered by the piston.

Fig. 1 is a sectional elevation of the engine, Fig. 2 is a detail of the valve G, and Fig. 3 shows the valve in another position. The engine comprises any desired number of cylinders A, disposed vertically, and each provided with an independent crank chamber B connected to the combustion chamber of the corresponding cylinder by air passage C, opening into the cylinder at D. The lower face of each piston E acts in the known way as a pump to draw air through the valve F into the crank case B on its up stroke, and to compress it therein on its down stroke. The connection between each crank case and the corresponding air passage C is regulated by a valve G controlled by the engine governor. In the passage C is a fuel nozzle H, which projects into the cylinder air port at D. Liquid fuel is supplied by the pipe K to the reservoir M and from thence by a pipe N through the chamber O to the nozzle H. A non-return valve P is disposed in the chamber O and a hand-operated valve Q is disposed in the pipe N to regulate the supply of fuel to the nozzle. Between the nozzle H and the valve Q an opening J is made, communicating with the air space around the nozzle. The reservoir M may be provided with a float if desired to



PETTER'S TWO-CYCLE OIL ENGINE.

control the flow of liquid. The valve G may be provided with holes and may be formed with curved faces R and S working over two or more holes T to regulate the quantity of air. The small holes X of the disc valve can be drilled to any suitable size, and form a convenient method of increasing the air supply to any degree which may be found necessary when testing the engine in order to correct the variations and inaccuracies which arise in the course of manufacture. It has the advantage that the additional area of the opening thus secured remains constant for a considerable movement of the disc valve across the opening. Fig. 3 shows the disc valve moved to a position leaving only a comparatively small opening in the port hole. U is a lubricator from which oil is conveyed to the crank case through the air valve F. The inside of the cylinder head is shaped as at V, corresponding approximately with the shape of the deflector. The sparking plug W is placed at a point where the explosive mixture is richest. When the piston is up, the holes at H and J in the fuel nozzle are acted upon by the vacuum in the crank case whereby the fuel is sucked into the nozzle. When the piston is down, the pressure on the crank case acts through the hole J upon the fuel in the nozzle and drives it out through the hole H, which is subject to the atmospheric pressure existing in the cylinder.

INSULATION AGAINST HEAT AND COLD.*

BY C. B. ROWLEY.

A material or medium which retards conduction and reduces convection and radiation to a minimum may be called heat or cold insulation. Heat insulation brings to mind hair felt used in building construction, oven, pipe, and boiler coverings. Cold insulation suggests materials used in refrigerating work. When choosing a material for a definite condition we are governed by its durability, cost and insulating value or efficiency. The insulating value is often spoken of as the co-efficient of conductivity, which is determined almost entirely in the laboratory.

Pipe and Boiler Coverings.—Materials for this purpose are made in two ways. One method is to place correct proportions of the insulating constituents in a mould and bake them; the other method consists of building up insulation by uniting with either glue or stitching, thin layers of insulating material. In the latter case, pipe covering is built up on a mandrel. The materials made in moulds are the 85 per cent. magnesia blocks, moulded asbestos blocks in which the percentage of magnesia is considerably less (around 35 per cent.), infusorial or diatomaceous earth and fire felt. The other type, which we have termed "built-up," includes such materials as aircell, asbestocel, indent, carocel, vitribestos, pyrobestos, sponge felt, wool felt, and hair felt. All of these different types of insulation have their particular places.

High-Pressure Insulation.—Pipes up to 2in. as a rule should be insulated with 1½in. thick covering. Pipes from 2in. to 4in. inclusive should be insulated with two layers of 1in. covering, broken joint construction. Pipes 4½in. and over should be insulated with two layers of 1½in. covering, broken joint construction. The fittings should be insulated with material similar to the covering and finished with asbestos cement having a canvas jacket neatly pasted over them. The type of covering for such work is 85 per cent. carbonate of magnesia, nonpareil high-pressure covering and sponge felt covering. Of these three the sponge felt possesses a great deal more durability and a higher insulating value than the others just named.

In case of superheated steam lines, a material such as fire felt should be placed next to the pipe in order that the severe heat may not come next to the covering. Sectional insulation is now made so that the first ⅛in. or ¼in. which comes next to the iron is this material. When you consider that a temperature of 450° is sufficient to start calcination in the case of magnesia I think you will appreciate the advisability of using a covering specially designed for this high temperature work. The insulation of boilers differs so widely that about all I can say is the insulation on a boiler should be equivalent to and preferably better than that used on the largest pipes.

Breeching and Stacks.—The exterior of flues and breeching may be insulated with materials similar to those for high-pressure pipe lines. In case the temperatures of the flue gases are severe the insulation is often held away by metal studs approximately 1in. in length. A very convenient and economical way is to attach the metal studs to wire lathing and then apply the insulation against the lathing, thus making a 1in. air space between the metal and the insulation.

When the flue gases contain chemical elements most destructive to iron, then it is wise to line the interior of breeching with either vitribestos or pyrobestos. This material consists of aircell sheets vitrified with a hardening solution so that temperatures as high as 700° can be constantly withstood. These sheets are often curved at the factory to fit various conditions, and in the case of stacks, angle irons are put on 3ft. centres horizontally and the sheets are then placed between these angles. The angles are drilled, 12in. centres, and spikes are then driven through the holes into the sheets which holds them rigid. The joints and the iron work, left exposed after the sheets are installed, are covered over with a special cement which will harden and withstand the temperatures to be encountered.

When conditions call for material to stand a temperature of more than 700° continuously, these sheets are often covered with a high temperature cement, approximately 1in. thick, which will withstand 1,200°. Such construction gives a well insulated flue for a minimum cross-sectional area of material and in some cases has eliminated the necessity of forced draught.

Low-Pressure and Hot-Water Insulation.—Standard thick magnesia is a very good material both for the boiler and pipe covering, provided there is no chance for damage being done by ladders, tools, or other power plant equipment. Magnesia covering and blocks are very fragile, and do not stand up on vibrating pipes or severe conditions. A fine aircell or asbestocel covering is recommended in case the working conditions are rather severe. This covering should be at least 1in. thick.

Underground Steam and Hot-Water Lines.—These should be carried in a tile conduit laid at least 3ft. below the surface of the ground. Pipe should be supported every 11ft. to 15ft., according to size of pipes, on rollers so that the expansion and contraction may be taken care of without strain on the fittings. All fittings should be screwed. 4in. tile underdrain should be placed below the conduit to carry off surface water. The pipes inside of the conduit should be insulated with a good grade of sectional covering, or a non-combustible conduit filler weighing not over 8lbs. to the cubic foot, should be securely packed between the inside of the conduit and the pipes. It is good engineering practice in the case of a fill, to allow at least 2½in. between the inside of the conduit and the exterior surface of the pipe. Two pipes are carried side by side in which case there should be an inch of space between the pipes. When three or four pipes are to be carried it is well to keep the two largest pipes on the top row, as a return line need not have as heavy insulation and can therefore be placed within an inch of the bottom of the conduit; this distance should be greater if possible. The back filling should be either gravel or cinders, and carried to a point at least 3in. above the horizontal joint of the conduit in order that surface water may not stand and thus work its way through this horizontal joint. The expansion of the pipe should be taken care of every 200ft. by placing in a manhole either a U bend or expansion sleeve. The insulating efficiency of underground conduit may be depended upon up to 90 per cent.

Out-of-Door Steam Lines.—Out-of-door steam lines should generally be insulated with twice as thick a covering as would be used on the same pipe indoors. Protect the pipe covering with a waterproof jacket of asbestos roofing, sized and painted canvas, or galvanised iron. A very good and common method of insulating out-of-door steam lines is to use the same kind and thickness of covering as recommended for interior work and then additionally insulate with 1in. of hair felt protected by one of the waterproofing jackets above-mentioned.

Out-of-Door Water Lines.—When writing specifications for covering out-of-door water pipe, the size of pipe, temperature of water, and velocity of water must be taken into consideration. In general, however, insulation should consist of two layers of 1in. hair felt securely wrapped around the pipe with the second layer breaking all joints with that of the first. Asphalte should be freely used to seal all joints. Over the last layer of felt place two layers of rosin-sized paper and a roofing jacket securely wired on with copper wire and all joints sealed tight. If canvas be used, instead of the asbestos roofing, it should be at least 8oz. duck thoroughly sized and painted with lead and oil, which process should be renewed at least every two years.

In case the out-of-door pipe contains still water and must be kept from freezing, it is necessary to run close beside a low-pressure steam or hot-water pipe and insulate as follows: Around the pipes apply wire lathing held 1in. from the pipes by metal studs; over this apply two layers of 1in. hair felt, breaking joints, and one layer of saturated asbestos felt; cover the entire insulation with one layer of three-ply roofing, cementing all laps, and additionally secured by independent strands of copper wire 6in. or 8in. apart. A strip of asbestos paper should be placed between the hot water or steam pipe and the hair felt; this paper is usually inserted between the wire lath and the first layer of hair felt.

Out-of-Door Insulation for Tanks.—Around the top of tank and around the bottom of tank securely fasten a heavy

* Abstract of paper read before the Cleveland Engineering Society, U.S.A.

galvanised wire or sheet iron strap. Running up and down the tank (fastened at the top and bottom of this wire or strap) place barbed wire, approximately 2ft. between strands; around this tank wind 1in. thick hair felt held firmly against the barbed wire with heavy twine. Erect against this 1in. hair felt more barbed wire running vertically and spaced approximately 2ft. between strands. Apply second layer of 1in. hair felt securely holding same in place with heavy twine, this second layer to break joints with the first layer. Cover this insulation with three-ply roofing jacket, all joints lapped at least 3in. and sealed tight, this roofing to be securely held by galvanised iron bands or hoops (approximately an inch wide by one-eighth inch thick), and made tight by means of bolts or turnbuckles. The top or roof of tank should be insulated with two layers of 1in. hair felt, or with 2in. thick pure cork sheets securely fastened and covered over with roofing above specified.

Cold Water, Ice Water, Brine and Ammonia Pipe Covering.—Covering for cold water, ice water, brine and ammonia pipes consists of sectional insulation composed of either wool felt, hair felt, or cork. The latter is manufactured in approximately 1in., 1½in., and 3in. thicknesses. The other coverings differ in thickness, and in the case of brine or ammonia pipe the hair felt and wool felt roofing insulation is built up on the job, by winding the felts (with roofing paper between) on the pipe, and sealing off all joints with brine putty. Where there are many fittings the hair felt is the best proposition from both the financial and durability standpoint.

Cold Storage Insulation.— Materials most frequently encountered are sawdust, shavings, mineral wool, scrap felt, feathers, cork, cocoanut fibre, bicarbonate of magnesia, infusorial earth, hair, and wool. Of all these materials, cork stands pre-eminent, as it alone possesses moisture-resisting qualities, low cost, and ease of application. In order to better appreciate this insulation, let us consider in brief the history and manufacture of cork products.

Cork.—The raw product is the bark of the cork-oak, a native along the shores of the Mediterranean Sea, also extensively found in Portugal, and the mountainous sections of Spain. The tree grows a gnarly bark which scales off from time to time as new bark forms. At the age of 30 years the bark is of sufficient thickness to be stripped. Unlike most trees, the removing of bark aids the growth and prolongs its life, some trees living more than 300 years. After being removed the bark is weighed, roughly baled, and taken, usually on burrow-back, to a central station where it is boiled. The boiling increases its volume approximately 25 per cent., and takes out considerable of the dirt and impurities. The bark is then scraped, again packed into bales and shipped to the manufacturers of cork products. The best material is used for cork stoppers from which there is a tremendous amount of waste, 60 to 70 per cent. This by-product, together with the coarser pieces of bark, go to plants where the cold storage cork sheets are made.

The by-product from the cork stoppers and the small pieces of coarser bark are sorted and screened into uniform sizes of approximately ¾in. diameter. None of the outside bark of the tree is used as it lacks elasticity and the essential binding properties. After the cork has been sized and cleansed (free from dust) it is placed in steel moulds and there compressed. While under pressure the cork is thoroughly baked and then gradually allowed to cool. This baking process drives out the moisture and causes the natural sap to form a glue which binds all the particles into a homogeneous mass. By driving out this moisture, and destroying the impurities, by the heat treatment, more air cells result and consequently a more efficient insulator is produced. Turning the sap into a glue greatly increases the waterproofing qualities, which is one of the large factors to be thought of in choosing an insulating material.

After being removed from the mould the edges of the cork sheets have to be trimmed and trued up which makes the finished product a 100 per cent. pure sheet of cork, 3ft. long, 1ft. wide, standard thicknesses of 2in., 3in., or 4in. Other thicknesses may easily be had by sawing these standard sheets. Other forms of cork board are made where the particles are united by means of asphalte to form sheets of the same size as spoken of in regard to pure sheet cork. Fine regranulated cork is a ground cork which has previously received the heat treatment. The by-product from the trimming of pure sheet cork is used for producing most of this material.

Suggestions for Thickness and Methods of Applying Cold Storage Insulation.—Allow 1in. of pure cork sheet insulation for every 10° Fah. difference of temperature between inside and outside of refrigerator, *e.g.*, if the inside of refrigerator is 50° and the outside temperature is 70° the thickness of insulation should be equivalent to 2in. of pure sheet cork. You will appreciate this is a rough rule, but it is one that will serve as a guide when there is to be a known temperature inside as well as outside of the refrigerator. Pure cork sheet is erected against fireproof construction by buttering the surface of the cork with approximately ½in. thick cement mixed in proportion of one part cement to two parts sand. In the case of ceilings the cork sheets must be propped for at least 24 hours, and often longer if cold or unusually damp weather prevails. When erecting one course of cork against another course of cork, Portland cement or asphalte is used as the bond, and hickory beef screwers approximately six to a sheet should be substituted in place of nails. In new buildings ceilings are insulated by placing the sheet cork in the forms before the concrete is poured.

Insulation of fireproof floors is usually accomplished by laying sheet cork in hot asphalte and mopping the top surface with this same material. A finish concrete working floor should be laid over the insulation at least 2in. thick and 3in. thick if trucking conditions are to be encountered. When erecting cork sheets against wooden sheathing a waterproof paper should be placed over the sheathing before nailing the first course of cork.

Dividing partitions whether they be one or two course work can be successfully built by means of erecting temporary studs which serve as a guide when erecting the first layer of cork. After a Portland cement scratch coat has been applied over the sheet cork these temporary studs are removed and the remaining portion of the exposed surfaces are then plastered. Walls of this character are rigid, durable, require less space and are more economical than a tile or brick wall against which the insulation is erected.

In irregular openings and places where difficulty is experienced in getting a true wall, fine regranulated cork should be used to fill all air spaces, and if a fill of 6in. in thickness or more can be utilised the sheet cork may be omitted if the refrigerator is not to be at a lower temperature than freezing. A very convenient way for holding a fill is by studs placed on edge, against the outside edge of which should be nailed paper and heavy wire lath. The exposed lath and surfaces of cork sheets, after the insulation has been erected, should receive a Portland cement finish approximately ½in. thick applied in two coats and mixed one part cement to two parts clean, sharp sand. The second coat may be a smooth float or trowel finish according to the type of building in which the refrigerator is located. It is wise to mark off the finishing coat into panels approximately 4ft. square so that when the cement sets, the checking will follow a definite line. Other materials such as lith and rock cork are installed similarly to cork sheets. Cold storage doors are now on the market insulated with various thicknesses of cork so that the door proposition is a very easy one to handle. Door bucks are at least 4in. by 4in., and the cold storage door frame is lag-screwed to these bucks.

Ice Bunkers. Ice bunkers differ so widely in size and shape that only the principles can here be given. The ice loading capacity should be from one-fifth to one-fourth of the total volume of refrigerator. The floor and one side of bunker known as the hot air baffle, should be insulated with the equivalent of 2in. of pure cork sheet in order to prevent sweating. In refrigerators 10ft. in width or less, one bunker is sufficient, making hot air baffle 12in. away from wall, cold air 10in. away from wall and extending hot air baffle to within 14in. of ceiling. If galvanised iron be used for lining, use not lighter than 22 gauge, lap seams in directions that water will drain. For refrigerators between 10ft. and 20ft. in width use two bunkers, making hot air baffles same dimensions as given above and allow 22in. between the cold air baffles in the middle of the room.

REAVELL'S TWO-STAGE AIR COMPRESSOR.

A SIMPLE and compact construction of 2 stage air compressor in which provision is made for ready dismantling, examination, and replacement of parts, has recently been designed and patented by Messrs. Reavell & Co., Ltd., of Ranelagh Works, Ipswich. Sectional views of the compressor are shown in Figs. 1 and 2. The pedestal or base is formed with bearings for the main shaft. A cylindrical recess A constitutes the bottom end of the first-stage cylinder. A suction valve B and delivery valve C is arranged as shown so as to be accessible for examination. The outer casing or water jacket is securely bolted on the pedestal. The cylinder liner is bored to form the first-stage cylinder D and the second-stage cylinder E each with a water-jacket space around it, joints being made between the flanges of the liner and the casing. The cover F contains the suction valve G and the delivery valve H of the second-stage cylinder; air is led from the delivery valve C to the suction valve G through a thin tube J that passes freely through a passage formed in the metal of the cylinder liner and serving as a connection between the water-jacket spaces around the two cylinders. As the tube J is perfectly straight and free from bends frictional losses and corrosion of the tube are reduced. The differential piston K which is fitted with packing rings is capable of being easily removed. The gudgeon pin L passes through the larger portion of the piston and is fixed therein by a grub screw; the casing and the cylinder liner are slotted, so that the projecting portions of the gudgeon pin can move up and down freely without being guided. The main shaft has keyed upon it eccentrics M, the straps of which have short rods or arms which engage with and oscillate about the gudgeon pin ends, being held thereon by washers and split pins. The jacket spaces can be filled with water by removing the plug N and the water can be run off by removing the drain plug O. Lubricant is admitted to the inner chamber of the low-pressure suction valve B from the sight-feed lubricator shown through the pipe P, and is carried by the air into the cylinders. The low-pressure delivery, high-pressure suction, and high-pressure delivery valves and their seats, plugs, and caps, are all interchangeable.

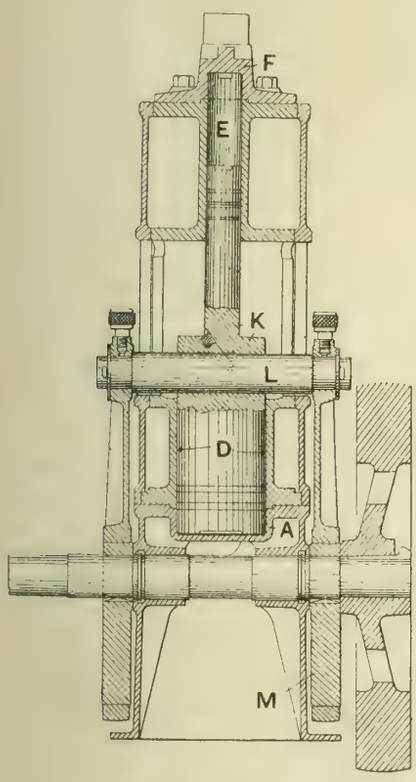


FIG. 1.

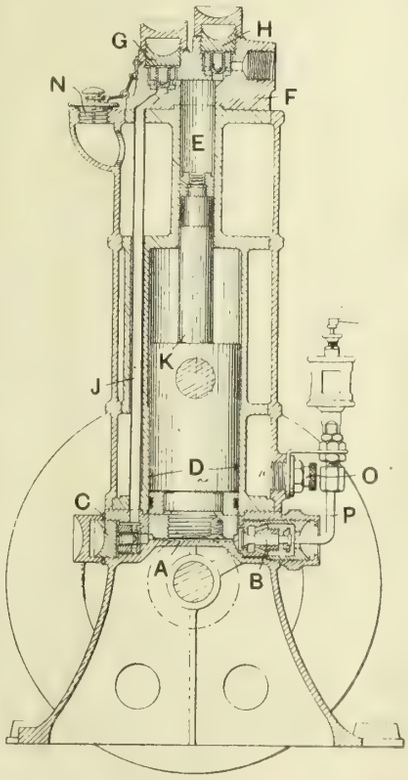


FIG. 2.

REAVELL'S TWO-STAGE AIR COMPRESSOR.

On rotation of the main shaft by hand or power the piston K will be reciprocated by the eccentric straps; on the upstroke of the piston, air enters through the suction valve B the first-stage cylinder D, the air in the second-stage cylinder E at the same time being discharged through the final delivery valve H to the reservoir; on the down stroke, air in the first stage cylinder D is discharged through the delivery valve C and passes thence through the tube J and second stage suction valve G to the cylinder E, the air being cooled during its passage through the tube J by the water which entirely surrounds it. The compressor being simple in construction, and easily and quickly dismantled, is consequently very suitable for use in the open or in places where it is likely to be somewhat roughly handled.

THE MANUFACTURE AND USE OF NICKEL-CHROMIUM STEEL.

IN a bulletin issued by the United States Bureau of Mines, Mr. H. D. Hibbard gives the following information relating to the manufacture and use of nickel-chromium steel.

Nickel-chromium steels, known in the trade as chrome nickel steels, are perhaps the most important of the structural alloy steels. Their field of usefulness is continually being enlarged by their application for new purposes and also by encroachment on the premises of some of the other alloy steels, notably of simple nickel steel, and they have almost wholly displaced nickel-vanadium and nickel-chromium-vanadium steels, which several years ago were in some considerable demand. The amount of nickel-chromium steels produced in 1913 was thought to be about 100,000 tons of ingots, all made in the open-hearth furnace with the exception of 2,000 or 3,000 tons melted in crucibles and electric furnaces.

Nickel-chromium steels are seldom used in any but a heat-treated condition. By suitable treatment pieces of small mass can be made to have as high physical properties as any steels known, with any elastic limit between 40,000lbs. and 250,000lbs. per square inch, accompanied by ductility that is high as compared with its strength, as the ductility naturally lessens as the elastic limit increases. Nickel-chromium steels can be made somewhat more cheaply than simple nickel steel of the same strength and ductility containing a smaller total of the alloying elements, and chromium is less costly than nickel.

Composition and Properties.—The upper limit of nickel in useful chrome-nickel steels is about 3·5 per cent., and all useful steels of this class, according to Guillet, are pearlitic. According to the same authority, when a chrome-nickel is case-hardened, the case is harder than that of a simple nickel steel. Some of the defects and troubles of chrome-nickel steels are like those of simple nickel steels. The composition and properties of six nickel-chromium steels in the natural or untreated state are given in Table I.

TABLE I.—*Composition and Properties of Nickel-Chromium Steel in Natural or Untreated State.*

Sample No.	Composition.							Tensile Properties.					Remarks.
	C.	Mn.	Si.	S.	P.	Ni.	Cr.	Tensile Strength.	Elastic Limit.	Contraction of Area.	Elongation in 2in.	Ball Hardness	
	P ct	P ct	P ct	P ct.	P ct	P ct.	P ct.	Lbs.	Lbs.	P ct.	P ct.		
1	0·55	0·41	0·22	0·03	0·02	1·53	1·14	96,000	75,000	66	31	185	Annealed.
2	·18	·27	·05	·04	·02	1·28	1·59	72,000	51,000	71	37	134	Do.
3	·15	·34	·13	·02	·01	1·28	·37	59,000	42,000	64	38	115	Do.
4	·29	·42	·07	·06	·02	3·86	1·48	-	—	—	—	—	Natual.
5	·25	·32	·10	·03	·02	1·45	1·20	96,500	81,500	68	25	—	Test piece.
6	·25	·32	·10	·03	·02	1·45	1·20	97,100	80,900	49	*7	—	Eyebar; full size.

* In 2½ feet.

The composition and properties of six nickel-chromium steels in the heat-treated condition are given in Table II.

Any one of the first three samples could be given substantially the properties of either of the other two by varying the temperature of the second heating. Most of the nickel-chromium steel goes into armour plate, projectiles, and automobile parts. Chrome nickel steel rails having 2 per cent. of nickel and 0·7 per cent. of

chromium have been tried by several railroads, but with unsatisfactory results. They resisted wear well as compared with simple steel rails, but broke badly both transversely and lengthwise, so that they were considered unsafe and consequently were removed. They were made by the Bessemer process and were not heat treated.

TABLE II.—*Composition and Properties of Nickel-Chromium Steel in Heat-treated Condition.*

Sample No.	Composition.							Tensile Properties.					Heat Treatment.	
	C	Mn	Si	S	P.	Ni.	Cr.	Tensility.	Elastic Limit.	Contraction of Area.	Elongation in 2in.	Ball Hardness.	Temperature at which Steel was quenched in water.	Temperature at which Temper was drawn in air.
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Lbs.	Lbs.	Pct.	Pct.		C.	C.
1	0·40	0·74	0·24	0·03	0·02	3·45	1·20	187,000	175,000	43	10	352	830	371
2	·36	·53	·11	·04	·01	1·55	·70	145,000	125,000	65	20	233	830	566
3	·21	·41	·22	·03	·02	3·52	1·11	110,000	75,000	66	24	215	830	682
4	·48	·44	·16	·01	·01	2·02	·98	212,000	186,000	46	10	445	843	427
5	·48	·44	·16	·01	·01	2·02	·98	140,000	120,000	61	18	287	843	649
6	·38	·28	·27	·02	·01	3·01	·65	114,000	90,000	69	25	266	843	649

Mayari Steel.—A so-called natural chrome-nickel steel is made from certain ores mined at Mayari, Cuba. The ores carry enough nickel to give 1·3 to 1·5 per cent. of nickel, and enough chromium to give 2½ to 3 per cent. of chromium in the crude iron smelted therefrom. When the iron is converted into steel by the pneumatic or open-hearth processes, the nickel is practically all present in the steel, but the chromium is of necessity largely wasted by being oxidised. Steel made in part of Mayari iron is giving good service in rails and particularly in track bolts, which are heat treated to give the metal an elastic limit of 75,000lbs. per square inch. Why these rails are satisfactory when other chrome-nickel steels were not has not been explained. The chief differences seem to be (1) that these Mayari steel rails have less of the alloying elements because Mayari iron is used only in part in them, and (2) that the steel is made in the open-hearth furnace.

The use of steel containing Mayari iron is increasing, and the demand is enough to induce the production synthetically of steels of the same composition by adding nickel and chromium to simple steels in the Mayari proportions. The Mayari steels are not included in the estimated quantity of chrome-nickel steels made, as already given. In fact it is likely that in the near future the tonnage of Mayari steels will surpass that of all the other chrome-nickel steels taken together.

Castings of Nickel-chromium Steels.—Castings are made also of chrome-nickel steel and may be used in the annealed or heat-treated conditions. Table III. gives the composition and properties of chrome-nickel steel castings.

TABLE III.—*Composition and Properties of Chrome-Nickel Steel Castings.*

Sample No.	Composition.							Tensile Properties.				Condition.
	C.	Mn.	Si	S.	P.	Ni.	Cr.	Tensile Strength.	Elastic Limit.	Contraction of Area.	Elongation in 2in.	
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.	Lbs.	Lbs.	P. ct.	P. ct.	
1	0·30	0·41	—	0·04	0·03	3·64	1·49	91,500	45,500	24	16·5	Annealed.
2	·33	·39	—	·04	·03	3·58	1·61	90,500	46,500	27	18·5	Do.
3	·30	·20	0·35	—	—	2·50	·50	110000	80,000	30	20	Heat-treated.

Tool Steel and Steel Wire.—We have received from Mr. G. P. Wall, Magneto Works, Penistone Road, Sheffield, a very serviceable catalogue and handbook relating to various sections of steel wire and tool steel rods manufactured by him. The catalogue also gives a great deal of practical information regarding the manipulation and heat treatment of tool steel, and is accompanied with some very useful tables relating to weights, strengths, and metric equivalents. Mr. Wall intimates that he will be pleased to supply a copy to any firm who might find them of interest.

TESTING FIREBRICK.*

BY C. E. NESBITT AND M. L. BELL.

THE use of refractory material in metallurgical operations is one which, as a rule, is given but very general consideration. The selection of a suitable refractory calls for a study, first, of the temperatures involved, and, second, of the nature of the hot material and resulting slag to which the refractory will be exposed. Refractories are generally used in form of bricks or blocks which are moulded from materials in the plastic condition, then burned. The resulting product is a solid of sufficient mechanical strength to permit its use for various forms of construction. The two most common raw materials for making refractory bricks are clay and a variety of silica called ganister. Other raw materials are gradually finding wider and more general use, but these two continue to be the important ones. Clay and silica rock suitable for bricks are widely distributed, but nature has very largely determined their physical properties. Each of these materials has varying physical properties which may be taken advantage of and incorporated into the finished bricks, the quality of which is largely dependent on the methods employed in their manufacture.

In its simplest terms a furnace or heating chamber consists essentially of a shell of brickwork sometimes bound together with a suitable framework of iron. Owing to various physical, chemical, and mechanical operations which take place in the furnace the refractory must meet certain demands to give a satisfactory life. No brick can be expected to be best in all physical properties, and it becomes necessary to select the brick which is best suited to withstand that particular condition imposed by the furnace. It may be that the brick will have to withstand the abrasive action of heavy, hard materials, the sudden fluctuation of temperature, the corrosive action of slag, or the action of load while at high temperatures. These and similar points should be considered, their relative importance determined, and the brick chosen should be the one best suited to resist that particular condition.

In the iron and steel industry the blastfurnace is one of the most important types of furnaces. In simple terms, it is a hollow steel cylinder, approximately 100ft. high and some 28ft. to 30ft. diam., lined with firebrick. In a furnace of 500-ton capacity, about 1,900 tons of ore, limestone, and coke are used every 24 hours. These materials, often wet or frozen, are fed in at the top and fall on the materials already in the furnace or roll over against the walls. Since this material must pass slowly through the furnace the wear on the lining is extremely heavy. The temperature at the top of a blastfurnace is low, but as the charge descends the temperature increases until the fusion zone is reached. In this zone the hard material composing the charge becomes a pasty mass which ultimately is melted and the brickwork then has to withstand molten iron and slag rather than abrasion or impact.

No blastfurnace is complete without its battery of stoves, in which no metallurgical operations take place. The object of the stove is to absorb heat rapidly and then as quickly give it up. Here a brick must withstand sudden thermal changes, abrasion, slagging, due to the dust carried by the burning gas, and possess good heat-absorbing qualities.

In one of the processes of converting pig iron into steel; a basic open-hearth furnace is used. This furnace is built up largely of silica brick, although the hearth is made up of basic materials because of the basic character of the slag, while the regenerators are of firebrick. Silica bricks are very sensitive to thermal changes, but owing to their infusibility and their ability to withstand heavy loads when highly heated, they are used almost without exception in open-hearth practice. Any variation in the method of manufacture which will tend to decrease the sensitiveness of silica bricks to heat changes, without sacrifice of their other good qualities, will directly increase the life of the furnace and materially lessen furnace shut-downs. In all soaking pits, heating furnaces, annealing furnaces, mixers, ladles, &c., the temperatures are not as high as in the open-hearth furnace; the brickwork here has mainly to withstand the action of the molten metal, iron scale, or slag. A general review of the conditions imposed on firebrick as used about iron and steel plants has pointed out two general

* Paper read before the American Society for Testing Materials, June 27-30th, 1916.

conclusions: (1) the life of a furnace is determined by the life of its brickwork, and (2) different furnaces demand different physical properties in the brick used.

A great many investigators have attacked the problem of refractories, the work having been done mainly from the standpoint of the inherent physical properties of the raw materials. The results are of high technical excellence and have been of value. In the majority of cases, however, the tests have not been applicable to brick as received by the consumer. He could not go out to his stock, select several bricks and quickly determine their value for his particular purpose. With this idea in mind each of the various conditions where firebrick are used was studied to determine the cause of failure. The next step was to imitate actual conditions of service in the laboratory. This meant that tests must be employed which were very severe, producing in a short time what in actual service might require months or even years to accomplish. To test brick cold and say that the result of the cold test was a measure of the performance when hot, did not seem justifiable. Another point was to make the tests such that the work could be done on the brick as received, and not on bricks prepared for the test.

In the study of service conditions, attention was first directed to the top of the blastfurnace. The average temperature at the top is about 260° C. The charging of a furnace is a nearly continuous operation, the material charged falling on the large bell, which when lowered allows the material, often wet or frozen, to slide off the bell and strike the walls of the furnace. Immediately the charge starts slipping and grinding its way slowly downward past the brick in the wall. These conditions required tests that would imitate impact, abrasion, and spalling.

Impact Test.—An impact test was first considered. The rattler and other similar tests were studied, but it was finally decided that some kind of a drop test would be the most practical, and would most nearly approach service conditions. After trying many shapes and sizes of falling weights it was finally decided to use a steel ball 2½in. diam. The brick was heated to 260° C. and the ball allowed to drop on the end of the brick from a height of 2in., then 4in., and so on, until the brick broke. The height to which it was necessary to raise the ball to cause fracture of the brick represents a particular quality, namely, resistance to impact.

The comparative strengths of brick to resist impact at ordinary temperatures and at slightly elevated temperatures are interesting. A brick heated to 260° C. and tested was 20 per cent. weaker than a brick of the same brand tested at 20° C., and 40 per cent. weaker when tested at 540° C.

Abrasion Test.—In developing an abrasion test it was found that others had abraded brick in the cold by means of an emery wheel. This idea was modified so as to test the brick while hot. A temperature of 260° C. was adopted for top-wall and pipe brick and 1,350° C. for all others. The reason for choosing 1,350° C. for the high temperature was that (1) it is a comparatively easy temperature to reach with a test furnace, and (2) while it might not represent the highest temperature in the furnace, it is above the melting point of cast iron and is applicable to all high-temperature furnaces used about iron and steel plants.

The brick to be tested was heated to 1,350° C. and then pressed against a carborundum wheel, pressure and time being constant. When the brick became cold the depth of cut was measured and the result reported as linear inches abraded in 5 minutes. This test developed the interesting fact that bricks are not always the same at both ends, for it was found that sometimes there may be 10 to 20 times as much abrasion at one end as the other.

Spalling Test.—Spalling was next studied. In brick work such a condition is usually the result of thermal changes, often accelerated by mechanical pinching. In actual service only one surface, generally the end or side of the brick, is exposed to the direct action of heat. After trying various tests it was decided to place the brick to be tested in the wall of the furnace so that only one end was exposed. The testing temperature was 1,350° C., and after a series of experiments as to the most satisfactory time for heating, one hour was decided upon, with 25 minutes cooling in a blast of air. To produce a measurable spall at least 30 operations of heating and cooling were required. This was too long, and it was decided to increase the severity of the test by cooling in water for 3 minutes, and so hasten the spalling. A series of tests determined that cooling in water was three times as effective as air cooling. The number of operations was accordingly cut down to 10. The amount of spalling is reported as the percentage loss in weight. This test applies only to firebrick.

Slagging Test.—The failure of brick work due to the corrosive action of slags is more prevalent than from any other cause. Not only is slag action marked in blastfurnaces, but also in open hearths, cupolas, and heating furnaces, and to a lesser degree in mixers, ladles, fireboxes, &c. During the development of a slag test the slag was first placed on the surface of the brick. It was next confined by the use of kaolin rings, but both tests were unsatisfactory. To confine a comparatively large portion of slag to any one portion of the brick it became necessary to drill a cavity in the brick and place the slag therein. Experiments were made to determine the effect of fineness of the slag, time of exposure to heat, and the effect of destroying the surface texture by drilling. To measure the slag penetration the brick is cut through the pockets of the slag and the area of brick penetrated by the slag measured with a planimeter.

Compression Test.—The ability of brick work to stand up under loads when highly heated is of great importance. A comparative test consisting of a modified Brinell ball test was used by heating the brick to 1,350° C., removing from the furnace and then forcing a 2½in. steel ball into the brick under a pressure of 1,600lbs. The depth of the impression was then measured when cold.

Expansion, contraction, and fusibility are important qualities of firebrick. For these tests the usual methods were followed.

As a result of a large number of tests following the methods outlined, it was found that firebricks tended to group themselves according to density. In general, bricks of high density, all other factors being equal, have the most desirable qualities, namely, least abrasion, good resistance to slag, and least compression. Spalling is very slightly increased but not to a dangerous extent if bricks are not over-burned.

As a measure of density, the apparent specific gravity is used—obtained by weighing and measuring the brick and not by suspension, as is usually done. Results show that various makes of brick have characteristic values for apparent specific gravity and that the method of manufacture greatly influences the density. Power-pressing a brick during manufacture up to 1,500lbs. per square inch has been found to materially improve the quality of most firebrick; beyond that figure very little improvement is made.

The laboratory methods suggested have been developed mainly with reference to bricks to be used in iron and steel plants. When modified they are applicable to almost any condition of service to which the bricks will be subjected. If a brick is to be used in a boilersetting, copper or lead smelter, calcining or roasting furnaces, the test should imitate these conditions, in order that the results be comparative. Conditions of service must be studied to learn what is demanded of a brick. When a laboratory test has been developed it must be confirmed by actual service tests. To compare the life of two similar furnaces built of different materials, or even the same furnace built of different materials at different times, does not necessarily mean that the material showing the longest life is the better, since the operating conditions may have been decidedly different. Conclusions can only be drawn when all conditions except brick quality are the same.

To derive the greatest benefit the consumer and manufacturer must work together. The manufacturer's interest must not cease with the shipment of his product. The consumer should provide all reasonable facilities for the manufacturer to study his product in actual service. It is only by such co-operation or exchange of information that the best results can be obtained.

At the present time the following machines and apparatus described are in a state of development and while they have been standardised for the test, the machines and methods themselves are not necessarily final. The machine for determining the resistance to impact consists of two vertical uprights 15ft. high, supporting two vertical and parallel 1½in. angle irons. The angle irons are placed so that their enclosed angles face each other and are braced 3⅜in. apart measured from the inside of the angles, so as to allow a ball 2½in. diam. to fall freely between them, the sidewise movement of the ball not to exceed ¼in. These angle irons are adjusted so that bricks of different heights may be placed under them and are

marked, beginning at the lower ends, so as to clearly designate successive heights of 2in. The test specimen is placed directly below the angle irons on a steel block of sufficient size to give a solid foundation. The upper face of the block is perfectly smooth and at right angles to the angle irons. The block is 6½in. by 15in. by 12in. and weighs 332lbs. The falling weight is a steel ball 2½in. diam. weighing 2·34lbs.

The brick to be tested is first carefully inspected, and, if necessary, ground on a carborundum wheel so that it sets firmly on one of its ends. On the other end of the brick the diagonals are then drawn to locate the centre. The brick is now placed in a cold furnace and heated at a uniform rate from atmospheric temperature to 260° C., so that at least one hour is required to reach the final temperature. The final temperature is maintained for not less than three hours.

The brick is now ready for the test and is placed on the steel block, so that the ball between the angle irons touches the brick at its marked centre. Iron blocks are placed around the brick until they are nearly level with the top of it, to prevent sidewise movement, but the brick is not wedged. The ball is now dropped from a pair of tongs on the end of the brick at successively increasing heights of 2in. until the brick fractures. Any fracture radiating 1in. or more from the point of contact of the ball is considered a fracture, and the distance in inches of the last drop is the result of the test. If the ball is allowed to drop again from the last height the brick gives off a dead or broken sound. The clear ring of a sound brick has disappeared.

Making a Compression Test.—The machine for determining the resistance to compression is a modified Brinell ball testing machine and consists of a 4in. I-beam, 10ft. long and weighing 75lbs., so arranged as to act as a second-class lever arm; that is, one end is the fulcrum and at the other end the weight is applied so as to produce the compression on the brick placed 6in. from the fulcrum. All bearings are knife-edged. The fulcrum end of the bar is mounted between two vertical uprights, 10in. channel irons, and so arranged that the height of the fulcrum may be adjusted by a handwheel to suit bricks of varying thickness. Six inches from the fulcrum towards the weighted end of the bar a spherical depression marks the location of the ball. The ball is a steel ball 2½in. diam. weighing 2·34lbs. The brick to be tested rests on a solid foundation directly below the depression. The bar alone produces a pressure of 850lbs. on the ball, and the balance of the weight is added at a uniform rate of 25lbs. per second by means of dry sand which flows from a hopper into a bucket attached to the end of the bar. Bar and sand together produce a total load on the ball of 1,600lbs.

The brick to be tested is placed in a cold furnace and heated slowly to 1,350° C. The heating as a convenience is done over night, at a uniform rate not to exceed 260° C. per hour. Total time of heating should in no case be less than six hours. The brick before testing should be maintained at 1,350° C. for not less than three hours. The brick is now removed from the furnace and placed flat on the foundation beneath the bar, and the bar lowered so that when the ball is in position in the depression, it is also in contact with the centre of the upper surface of the brick. The weighted end of the bar is then gently released and the flow of sand immediately started. The time required to remove the brick from the furnace and apply the load is less than one minute. The pressure is maintained for five minutes, starting from the time the bar is released. The brick is then removed from the machine and allowed to cool. When cold the depth of penetration produced by the ball is measured by placing centrally over the depression a flat rectangular plate 3½in. square and ⅛in. thick, at the centre of which is mounted at right angles to it a micrometer depth gauge. The lower end of the stem of the micrometer is rounded so that it has the same radius as the 2½in. ball. The depth at the centre of the depression is measured to 0·001in.

Making an Abrasion Test.—The abrasion testing machine consists of a carborundum wheel mounted on a suitable stand and revolving vertically. In front of the wheel and resting on the stand is an L-shaped plate 6½in. by 16in. by ¼in. resting on roller bearings, and forced towards the wheel by means of a right-angle lever arm, and suspended weights. The upper surface of this plate is 1¼in. below the horizontal radial line drawn from the centre of wheel. All points of contact on the lever arm are knife-edged and friction is reduced to a minimum. The carborundum wheel is 18in. diam., has a 2in. face and 1½in. centre hole. The wheel is motor driven and has a surface speed of 1,640ft. per minute and is to be redressed when the corners wear away ¼in. of their original radius, or as soon as the face ceases to be at right angles to the side of the wheel. The pressure of the brick against the wheel is 10lbs. per square inch of brick in contact with the wheel, excluding the pressure required to move the brick.

The brick before testing is ground cold to a uniform thickness of 2·35in. for 2½in. brick and of 2·80in. for 3in. brick, and the ends ground so that the testing wheel cuts through this thickness. The depth of this preliminary cut is measured at its centre, using the rectangular plate described under the compression test. The brick prepared for test is heated the same as under the compression test, except in the case of top-wall and pipe brick, which are heated the same as for the impact test.

The brick is then removed from the furnace, placed flat on the plate in front of the wheel so that the wheel enters the preliminary cut, and is then abraded for five minutes. The time is taken with a stop-watch. In the case of soft brick which abrade very rapidly the test is run for a fraction of the period, and then calculated to the five-minute period. The brick is now returned to the furnace and reheated for not less than one hour. The test is then repeated on the other end of the brick. When cold the depth of cut on both ends is measured, and the difference between the preliminary and the final cuts is the result which is reported. Preparatory to the spalling test, the furnace is heated to 1,350° C. and held at this temperature for about one hour. The bricks to be tested are dried at 100° C. for at least five hours, weighed, and then placed in the doorway of the furnace, their ends flush with the inside of the wall. In case a sufficient number of bricks are not being tested to entirely fill the doorway, the remainder of the space is filled in with other bricks to ensure heating the ends only. The bricks are now heated for one hour and plunged separately into 2 galls. of water at 20° C. to a depth of 4in. and held there for three minutes. The bricks are then removed and allowed to dry for three minutes in air. To indicate three-minute periods a stop-watch is used. The bricks are then placed in the doorway of the furnace as before and operation repeated for a total number of 10 times. The bricks are now dried at 100° C. for at least five hours and all particles, which can be easily broken off with the fingers, removed. The bricks are then weighed and the percentage of loss calculated from the original weight.

Making a Slagging Test.—In preparing the sample for the slagging test, the 9in. by 4½in. unbranded side of the brick is bisected by a line across the narrow dimension and diagonals drawn on each half. At each intersection of the diagonals a circular cavity is drilled 2½in. diam. and ½in. deep at the sides. The drills are $\frac{5}{16}$in. thick and 2½in. wide, measured diagonally across opposite corners, while the point of the drill includes an angle of 150°. A template is made of $\frac{3}{16}$in. sheet steel to ensure that all drills are ground properly. To ensure a standard depth of cavity, two inverted U-shaped pieces of metal are clamped to each drill when in use and adjusted so that drill cannot enter the hole more than ⅛in., measured on the side of the drill. The cross-section of the cavity passing through the deepest point has an area of 1·7 sq. in., and is checked up for size and depth by a template. The pressure used in drilling must not be so severe as to partially crack the brick.

After the cavities have been drilled and cleaned of loose material the bricks are placed level in a cold furnace and heated as in the compression test. When 1,350° C. is reached 35 grams of standard blastfurnace slag are placed, by means of a long rod with a spoon-shaped end, in one cavity, and 35 grams of standard heating-furnace slag in the other cavity. The slags used shall have approximately the following analysis and melting points:—

	Slag.	
	Blast-furnace, per cent.	Heating Furnace, per cent.
Silica (SiO_2)	38·0	35·0
Iron (Fe)	1·5	44·0
Manganese (Mn)	1·0	0·5
Alumina (Al_2O_3)	14·5	6·0
Lime (CaO)	42·0	1·5
Magnesia (MgO)	2·0	0·5
Sulphur (S)	1·0	
	Deg. Cent.	
Melting point	1,260	1,260

The fineness of the slag is such as to pass a 40 mesh sieve. The bricks are kept at a temperature of 1,350° C. for two hours after the slag is added, at the end of which time the furnace is allowed to cool, or the bricks may be removed from the furnace and allowed to cool in air. The bricks when cold are sawed lengthwise at a right angle to the unbranded side, so that one side of the cutting wheel cuts through the centre of the drilled cavity, and this area of slag penetration together with the cavity is measured with a planimeter. The area of the original cavity is subtracted, giving the result in square inches of slag penetration. The wheel used for sawing the brick is a carborundum wheel 12in. diam., ⅛in. thick, and 1¼in. centre hole.

The test specimens for determining the softening temperature are cut by means of the saw used in slagging test from the corner of the brick, in the shape of a triangular pyramid similar to that of a Seger cone. They are 3in. high and the base should not be less than 1in. on the side. The test specimen, together with a series of Seger cones, is set in some good refractory material which will not flux with the sample. The series of cones used includes numbers both below and above the cone at which the sample is supposed to soften. The whole is placed in a gas-fired furnace and heated at a uniform rate, not to exceed 600° C. per hour. The softening temperature is considered that at which the specimen either bends double, sags, or puffs out of shape and is determined by Seger cones.

Testing for Expansion and Contraction.—The machine used for the measurement of expansion and contraction consists of a micrometer mounted on a steel post, which in turn is mounted on a steel plate 24in. by 6in. by ½in. To the stem of the micrometer is fastened a steel disc 1in. diam. and ⅛in. thick. In line with the micrometer is a second steel post on which is mounted a ¼in. sliding steel rod with a similar circular disc, as with the micrometer. The rod can be adjusted so as to determine measurements up to 14in. To ensure that this rod is properly set standard bars 3in., 5in., 9in., 11in., and 13in. long are used. In preparing the brick for the test, the ends of the brick are ground so as to be parallel to each other at right angles to the sides. The length is then measured cold. The brick is then heated as in the compression test—or as for the impact test in the case of top-wall and pile brick—removed from the surface and measured hot. The removal from the furnace and measurement usually requires about 30 seconds. The result is calculated to inches per linear foot.

Test for Size.—The size is determined by the use of the micrometer described under expansion and contraction. All measurements are made while the brick is at atmospheric temperature. Small particles of sand, clay, or foreign matter adhering to the brick are removed before measuring.

FURNACE GAS FOR BOILERS.*

BY K. HUESSENER.

THERE are four causes for low boiler efficiency in the utilisation of blastfurnace gas: (1) Incomplete combustion. (2) Combustion with large excess of air. (3) Water vapour in the gas. (4) Deficiencies in the boiler plant itself.

The highest combustion temperature is obtained when the gas is fairly dry and burned without excess of air. For most blastfurnace gas this temperature is between 2,450° and 2,500° Fah. with cold gas, and from 2·8 to 11·8 per cent. higher with gas of a temperature of 200° to 600° Fah. It is an accepted rule that for the same quantity of any given gas passed in a given time, the stack temperatures will be in inverse relation to the combustion temperature. This shows the importance of a low excess of air, as a large excess will not only increase the volume, but also the temperature of the waste gas.

Fig. 1 shows the effect of excess air, water vapour, and unburned CO on the combustion temperature, and gives the losses of both sensible and latent heat due to incomplete combustion for gases containing 25 to 30 per cent. CO with 0 to 13 per cent. CO in the waste gas without excess of air. If the analysis of the waste gas shows excess of oxygen despite the unburned CO, both CO_2 and CO must be multiplied by the factor depending on the amount of oxygen in the waste gas. The value of these factors is given by Fig. 2. The chart is correct for all gases containing 38 per cent. $CO + CO_2$, 3 per cent. H_2, and 59 per cent. N_2, dew point being 120° Fah., and the gas temperature 400°.

Fig. 3 illustrates the effect of water vapour in the gas on the combustion temperature. It is based on burning blastfurnace gas with 10 per cent. excess of air, the air being at 60° Fah. and carrying different amounts of water vapour per cubic foot of dry gas measured at 60° Fah. and atmospheric pressure. This curve will answer questions as to the temperature to which blastfurnace gas should be cooled to give the best efficiency. Without exceptionally cold water, gas cannot be cooled below 75° Fah. Even this temperature will be seldom obtained, as it is usually profitable to use cooling water from the blastfurnace for washing purposes, so that the above temperature usually lies between 80° and 100° Fah. The

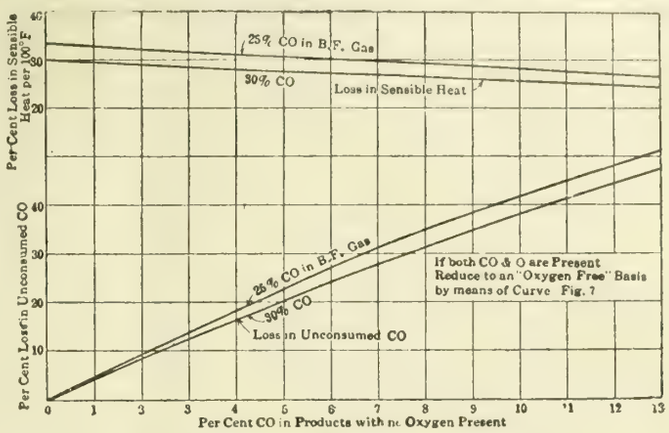


FIG. 1.—LOSSES DUE TO INCOMPLETE COMBUSTION.

difference in the combustion temperature will not be greater than about 40° Fah. or less than 2 per cent. Heat abstracted by water vapour in the waste gas is negligible.

It has been held that cold clean gas is preferable to hot unwashed gas. This does not apply to water-tube boilers where the tubes can be cleaned once each turn. Fig. 4 gives the thermal capacity of the various constituents of blastfurnace gas from 60° to 1,000° Fah., and may be used to ascertain the value of the sensible heat in the gas. Hot gas containing, say, 107 B.T.U. both in latent and sensible heat is just as valuable as cold gas of 60° Fah. containing the same amount of heat in the latent form alone. A boiler efficiency of 75 per cent. or higher should be obtained without difficulty with uncleaned gas. This efficiency on hot gas corresponds to

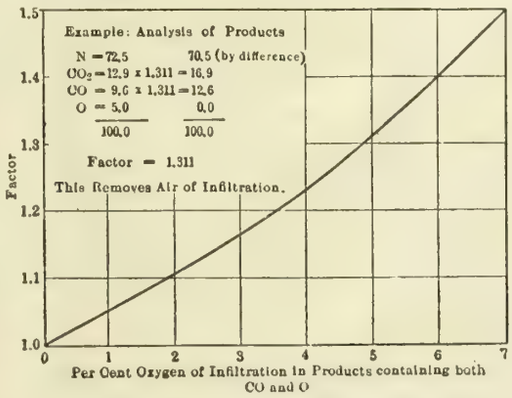


FIG. 2.—FACTORS FOR CORRECTING ANALYSES.

an efficiency of 80·5 per cent. on cold gas, and unless this latter figure can be exceeded there would be no profit in washing the gas.

Fig. 5 shows losses of sensible heat due to washing, while Fig. 6 shows the effect on combustion temperature of sensible heat when the gas is burned with excesses of air of 10 to 50 per cent. respectively. Fig. 7 shows the percentage losses for each 100° Fah. rise of temperature over the boiler house temperature, for varying CO_2 in the waste gas, from furnace gases containing 25 to 30 per cent. CO.

Bad boiler conditions and the losses resulting therefrom are: Defective brickwork, causing air leakages; insubstantial brickwork, causing high radiation and conduction losses; lack of boiler houses with the same results; defective baffles; scale; or too short passages for the products of combustion.

* Abstract of paper read before the American Institute of Mining Engineers.

The effect of air infiltration is shown by the following figures obtained at Johnstown:—

	Gas Pressure, 1·5in.					Gas Pressure, 3·5in.	
CO_2 ...	11·7	13·0	13·3	18.8	19·7	15·0	18·0
Rear temperature, deg. F. ...	626	620	616	578	577	580	545

Air infiltration here caused loss not only because it all had to be heated to stack temperature, but also because it resulted in an increase of stack temperature, thus reducing the heat absorption capacity of the boiler tubes.

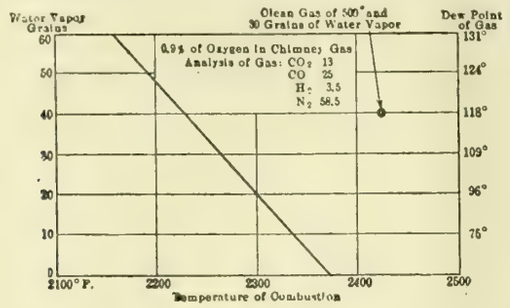


FIG. 3.—TEMPERATURE OF COMBUSTION OF BLAST-FURNACE GAS.

Gas burned with air at 60° Fah. and 10% excess air.

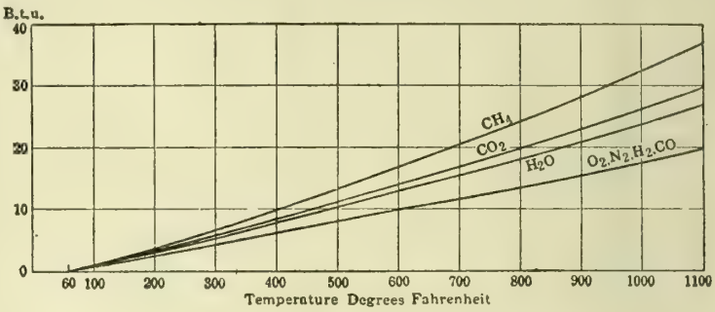


FIG. 4. THERMAL CAPACITY OF GAS OF DIFFERENT TEMPERATURES.

Gas saturated with varying amounts of water vapour per cub. ft. of dry gas measured at 60° Fah. and atmospheric pressure.

As regards boiler loads, high boiler efficiencies are compatible with overloads of 200 per cent. or more. The load depends on the chimney draught, and the limit is not reached until all dampers are wide open and balanced draught is established in the combustion chamber. At this draught the boilers receive all the air and gas which the stack can handle. Further increase of boiler capacity beyond this point may be made by the installation of induced draught. The maximum boiler load is dependent somewhat on the dust in the gas. The limit is reached when it is no longer possible to keep the tubes clean by blowing once every turn. This limit is about 180 per cent. of the capacity. This load, however, can be exceeded if the gas is cleaned.

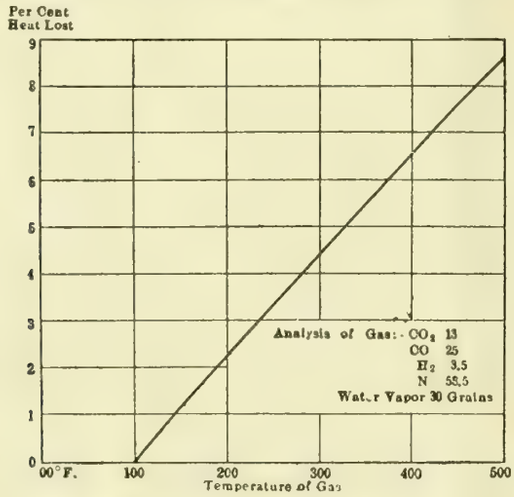


FIG. 5. LOSSES DUE TO WASHING.

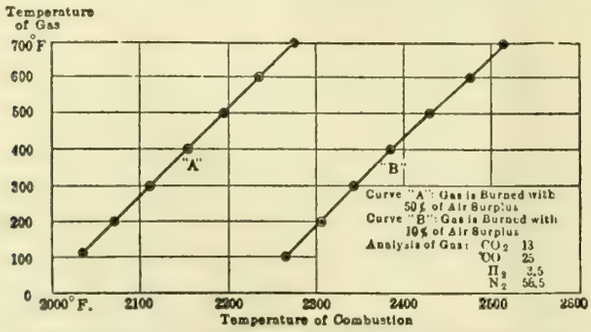


FIG. 6.—COMBUSTION TEMPERATURE WITH VARYING AMOUNTS OF EXCESS AIR.

Boiler construction has considerable influence on the economy, even aside from the condition of the boiler setting. While the one-pass boiler is considered almost hopeless from the standpoint of efficiency, nevertheless the author found these boilers could be run on 100 per cent. load with an efficiency of 75 per cent. Attempts to overload, however, were futile. The chief disadvantages of the one-pass boilers are the difficulty of keeping them air tight, together with a large radiation and conduction loss in comparison with their capacity. Inasmuch as it is possible to run this type of boiler on gas with high efficiency at its rated load, it will not pay to install more modern boilers for the purpose of increasing the efficiency, if ample capacity in one-pass boilers is available. Equally good efficiencies can be obtained on all types of boilers, provided the combustion arrangements are carefully designed.

The factor of second importance is that of draught. The statement that a burner of the type which employs a preliminary mixture of gas and air provides its own combustion air independent of the chimney draught is not wholly true. The ispiration of any burner is chiefly dependent on chimney draught and stands in direct relation to the velocity in the mixing chamber. In order to keep the relation between the gas and aspired air constant, the pull and velocity of the gas and air mixture by chimney draught must be kept constant, or the quantitive relation between the gas and air will be upset. The importance of draught regulation depends on the variation in the gas pressures. Where these variations are small, the draught regulation is of relatively small importance. It is, however, of great importance where it is desired to burn gas with a low excess of air, for with the dampers in a stationary position any increase in the gas pressure necessarily results in incomplete combustion. It is not safe to raise CO_2 higher than 21 per cent. without automatic draught regulation, whereas with such regulation 24 per cent. CO_2 can be safely maintained.

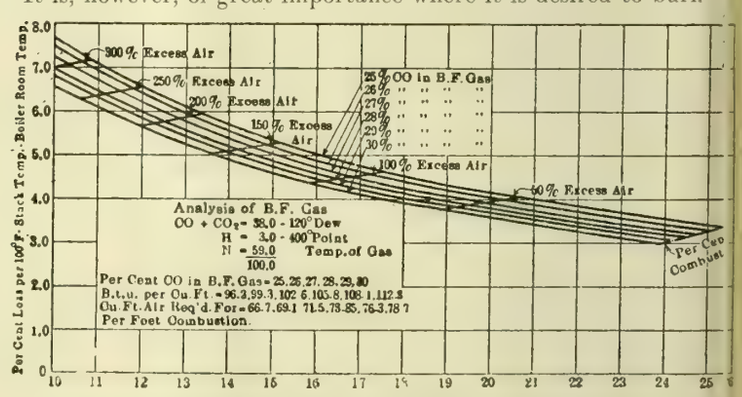


FIG. 7. PERCENTAGE LOSSES OF HEAT IN STACK GASES BASED ON THE CO_2 CONTENT.

Exhibition of German and Austrian Catalogues in London.—In order that British manufacturers may have an opportunity of familiarising themselves with German and Austrian methods of advertising, the Board of Trade have collected over 5,000 specimen catalogues of German and Austrian origin, and these may be inspected at the Foreign Samples Section of the Commercial Intelligence Branch. An index has been prepared, in which the catalogues are classified. Copies of this index may be obtained by United Kingdom manufacturers on application to: The Director, Commercial Intelligence Branch of the Board of Trade (Foreign Samples Section), 32, Cheapside, London, E.C.

GAS EXPLOSIONS IN FLUES.*

EXPLOSIONS in flues and similar situations are really cases of rapid combustion of gas. Combustible gas may be, in the first instance, kept apart from air, and then supplied through a burner to burn in an atmosphere of air, under which conditions the action is under complete control. When, however, the gas and air become intermixed at a temperature too low for ignition, the resulting mixture is in such a condition that when a light or spark is brought into contact with any part ignition is produced, which extends through the mass with such rapidity that the audible sensation appears to be instantaneous. The combination of combustible gas with the oxygen of the air is attended with as much heat as would be produced in a jet, but with the same rapidity as the flash, so that the whole mass of gas and air is raised to a high temperature and the explosion produces a corresponding pressure, whereby much damage is caused.

Coal gas, as from the public supply, is produced in retorts of various types, which are raised to high temperatures, whereby the gases are driven off. Gas of similar nature is produced in coke ovens or by heating of hydrocarbon oils, or in other ways. In gas producers of various types a limited supply of air is admitted, whereby an appreciable and additional amount of carbonic oxide gas is produced and delivered in mixture with the simple coal gas. The carbonic oxide is also a combustible gas, so that the mixture is equally prone to explosion.

The coal gas which is produced by the irregular action of boiler furnaces is comparable with gas as supplied for illumination and other purposes through the public mains, although the former is more variable in composition, and probably is never free from air. A mixture of one volume of illuminating gas with from two and a half to 19 volumes of air will explode on the application of a light or a spark to the bottom of the mixture. A mixture of from three and a half to 10 volumes of air with one of gas will explode if lighted at the top.

Coal gas is much lighter than air. The specific gravity of pure coal gas, as compared with pure air, is usually from ·4 to ·5, but may range from ·25 to ·8. Moreover, the gas as given off by a banked fire is most probably at a temperature distinctly greater than the temperature of the admixed air with which it may be in contact in the flue. The combined effect of these two conditions produces a strong tendency in the gases to pass in a stratum along the upper part of flues and to accumulate in any upward cavity to which it may have access.

It is obvious that if the roof of the entire flue should rise continuously from the fire to the chimney without dips, dampers, or other interruptions, there would not be any opportunity for gases to accumulate, and they would pass off as rapidly as they were produced. In a Lancashire boiler set with a downtake at the back end, a small opening is sometimes cut through the brickwork at a high level between the downtake and the flue, providing a direct course for the gases. This, however, allows hot gases to reach the flue, and thereby incurs a loss of trifling amount.

It has already been stated that if the combustible gas and the air were to be kept apart they would be quite under control. This point must, however, not be extended to imply safety in the present connection. Firstly, diffusion of gases must ensue and cause mixture which must, over extensive areas, involve absolute certainty of explosion on the application of a light. Secondly, if special conditions were in force to prevent diffusion, and if the boundary were sharply defined with gas above and air below, the liability to explosion would still exist throughout the length and width of the contact surface between gas and air; possibly, this particular phase of the question involves greater danger than any other.

The simplest case of flue explosions is found where a very hot fire is loaded with fuel in such a manner as to produce coal gas, which may be given off free from mixture, or with admixture of carbonic oxide, due to the passage of a strictly limited amount of air through the bed of fuel. In either case, up to this point, the gas is practically in a non-explosive condition. This general condition is very common in the banking of fires for the night's stoppage. If, however, prior to banking, the fire is allowed to burn down without receiving careful attention, it will have become thin in some parts, and probably large sections of the grate will be quite bare. In either case the fire may in such parts fail to possess sufficient vitality to continue alight, so that air is admitted without change through such parts of the grate. Alternatively, the whole grate may carry fire in all degrees of strength, so that strong combustible gas is given off in one part, varying to practically pure air in other parts. Thus the gases as a whole, when mixed together, may be in a highly explosive condition, and in the course of a night the whole length of flues may be charged with such gases. If a light were applied, or a spark were to reach the mixture, a violent explosion would be inevitable, and this is frequently effected by the action of the stoker in breaking up the fire, which brings incandescent fuel to the surface or allows a stream of incandescent gas to pass along the flues. In many such cases safety can be assured by first opening the dampers and firing doors in the morning and allowing time for the explosive gas to be cleared out up the chimney before the fires are broken up or touched.

It often happens that flues, economiser spaces, &c., become charged with a mixture which contains so much air as to form a strong explosive mixture with coal gas. In such case the result is very similar to that in which the mixture is effected in the furnace, but the damage caused by explosion may be located between the boiler and the chimney. Here again the explosion cannot be started without introducing a medium of high temperature into the explosive mixture of gases. This is most likely to be effected in the furnace—as before—and transmitted by a weak mixture of explosive gas to the stronger mixture in the part in which the destructive effects are most clearly manifested.

From the above it follows that the fires should receive careful preparation before banking for lengthy periods. Cleaning or removal of ash should be done a short time previous to stopping time, and the fires should be afterwards burnt to a suitable temperature and bulk; then they should be levelled to approximately uniform thickness and the banking fuel also applied to an approximately uniform thickness.

In connection with the banking of fires, the adjustment of the dampers is an operation of some difficulty. It is generally impossible to shut the damper close to the stops, as this would cause the escape of smoke or gases to such an extent as to fill the boiler-house to suffocation. A little further opening of the damper may stop the escape of gases into the house, but may not effect their passage up the chimney; the gases therefore accumulate in the flues, the economiser space, and any other cavities. Opening to an appreciably greater amount involves further difficulties, one of which is the "burning out" of the fires.

In ordinary cases the difficulties in connection with adjustment of dampers are completely overcome by arranging to shut each damper close to the stops and provide sufficient area for the occasion by boring holes in the damper. Such holes must be placed in the upper part of the damper, so as to pass the light gases, whereas if they were placed at a lower level they might pass stagnant air and omit to pass the combustible gases. The holes should be of 1½in. to 2in. diam., and sufficiently numerous to suit the case. It is better to drill the holes one or two at a time, so as to avoid the provision of more holes than necessary. If, however, this is done the excess holes may be stopped, preferably by the use of screwed plugs. In special cases a supplementary by-pass may be adopted, in principle equivalent to general practice in connection with steam stop valves or gas-supply fittings. The leading point to remember is that the damper may, under all ordinary conditions, be closed against a definite stop.

It is obvious that explosion may be produced by mixture of air and combustible gases from other sources than the ordinary furnaces of steam boilers. Explosions have occurred in connection with ordinary Lancashire boilers when hand-fired with wood waste or other bulky material liable to rapid gasification. These explosions are due to the choking of the furnace by a close mass of the fuel, whereby the air is largely excluded from the fire, during the period when combustible gas is being distilled, while a moderate amount of air enters at the back end of the grate, or elsewhere, and becomes mixed with the gas. Such a mixture may accumulate until the fire

* From "Vulcan," the official organ of the Vulcan Boiler and General Insurance Company, Ltd.

burns through the fuel and effects an explosive ignition. In such a case the obvious remedy consists in avoiding the choking of the fire, *i.e.*, by feeding in smaller quantities at shorter intervals of time.

Many explosions have occurred in connection with oil firing. Practically these are true gas explosions, as liquid fuel is virtually converted into gas before burning. These accidents have principally arisen in one of two ways. Firstly, the oil is turned on and gasified during some appreciable length of time before lighting, so that the furnace is more or less completely filled in the meantime with an explosive mixture of gas, which is fired when the jet is lighted or when it is brought into a full flaming condition. This point may be illustrated in any gas-lighting burner which is enclosed by a lantern, or even by the fittings of an ordinary incandescent burner. If a lighted taper is held to the burner, and the gas is afterwards turned on, the gas is lighted in silence. If, on the other hand, the gas is first turned on and allowed to accumulate in the casing, then the taper is applied only a few seconds later, the gas will ignite with explosive violence. In the second division some part of the oil escapes the gasification process by reason of some defect in the burner, while the flame is burning more or less imperfectly and the mixture is fired when the temperature of the flame is increased.

Explosions have occurred in connection with the crank chambers of high-speed engines in which the crank pins are lubricated by spoon. The agitation of the oil raises a kind of oil-mist which is easily ignited by a lamp inadvertently inserted for examination of bearings, &c. Obviously the formation of oil-mist in this way is promoted by the heat from a defective bearing.

Solid carbonaceous fuel burns under complete control when supplied with air, and the rate of combustion is regulated in accordance with the quantity of air brought into contact per second or per hour. With a feeble supply of air the fuel burns very slowly with a dull fire. With a more abundant supply of air—as with forced draught—the fuel is more rapidly consumed and intense incandescence is produced. When gaseous fuel is supplied, or is produced adventitiously, apart from flame, spark, or high temperature, it may be mixed or stratified with air without firing. If, however, any part of such compound should be ignited, the fire extends with great rapidity throughout the whole mass. Such explosions, however, are usually much less violent than those which are produced by solid military explosives, by detonation produced by a primary explosion of special force.

The amount of force produced in a gas explosion principally depends upon the accuracy and the homogeneity of the mixture. Generally, the air is in excess, so that the gas is completely consumed and surplus air is present to prevent the temperature of the resulting gases from attaining the maximum. The amount of energy developed in the form of heat is definitely measured by the temperature and the quantity of gas heated. The heat produced is imparted to the whole mass of gas practically without loss or qualification. As an example, a gas may be assumed with a calorific value half as great as that of pure marsh gas. If this is fired with an amount of pure air just sufficient to effect chemical combination, the pressure will rise to 62lbs. per square inch above the atmosphere at constant volume. As already noted, the air is, in first instance, usually considerably in excess, so that the pressure will not reach 62lbs., but a much lower pressure will suffice to cause much damage. On the other hand, in some cases the strength of the gas is liable to be more than equal to half the strength of pure marsh gas. The oxygen of the air is, obviously, the active agent in producing the explosion. If this could be supplied apart from the accompanying nitrogen, the heat generated in the explosion would be distributed over a smaller amount of resulting gas, and would give a higher pressure upon a smaller area. In other words, the same amount of force would be concentrated upon a smaller area.

Mixtures of combustible dust and air are also liable to explosion in a manner similar to gas and air. Obviously, the dust must be in the form of a cloud suspended in the air. Some of the earliest accidents of this kind were in connection with the dust chambers of flour mills. In other cases, fine sawdust has been the combustible element, and in recent years most disastrous explosions have occurred with coal dust in mines. The importance of this question as affecting the working conditions in coal mines has led to the institution of many experiments on a large scale, in some of which startling results were obtained. A gallery of nearly a thousand feet length was prepared, about two-thirds of which was made of boiler shells 7ft. 6in. diam., and of strength to burst at 160lbs. pressure. Some of these were shivered, and the fragments dispersed over great distances. Dr. Harger has shown that a comparatively small amount of CO_2 materially reduces the liability to explosion.

The principal interest of the above question, in the present connection, is in the fact that many explosions in flues have been caused by coal dust. Principally these have arisen in connection with the adoption of dust firing of boilers, and particularly by opening the fuel valve without ensuring that the jet of dust fuel should be simultaneously lighted as already explained in connection with the starting of gaseous or liquid fuel jets. It is, however, quite possible that dust explosions may occasionally arise in connection with the flues of coal-fired boilers; perhaps the most likely manner would be in breaking up a fire which has been banked with dusty fuel, and in which there is draught power to disperse coal dust equal to half an ounce per cubic foot of space.

Accurate proportions to obtain perfect combustion are about 1lb. of good fine coal dust to 133 cub. ft. of air, or, say, one-eighth part of an ounce per cubic foot of air. Four ounces of dust per cubic foot of air was, however, the quantity of dust used in the experiment above referred to; in such cases a considerable surplus of coal dust remains unburnt.

Explosive mixtures of either gas and air or of coal dust and air possess many features in common, whether they are produced in flues or in mining operations. It is obvious that the ultimate origin of the mixture and the proportions necessary to produce explosive chemical combination are practically identical. It may, therefore, be indirectly useful to make reference to some points whereby the occurrence of colliery explosions are obviated. These are of more interest in regard to the physical characteristics of the mixture than to direct applicability to the present question.

Primarily, explosion is caused by the application of heat sufficient to produce high temperature, by diverse means, including contact with hot solid bodies, hot gas, or sparks. The spark may be produced by electric current, hot glowing points of combustion, or by friction. Sparks by friction are usually produced in connection with mechanical details which are overloaded, or overheated by deficiency of lubrication, or by accidental contact of moving details. Casual sparks obtained in this way are attended with great danger, but often occur without causing explosion. In 1760 a flint and steel mill was designed by Speeding, intended to provide a light of sufficient power to give safe and useful illumination in a fiery coal mine. It was, however, found in the mine that explosions were caused by the sparks produced and the project collapsed.

Glowing points of combustion in the present connection are most frequently produced by light shavings, paper, &c., which may be ignited in the fire and carried forward by the draught until they meet with a pocket of explosive gas in the flue. Sparks from electric current may be produced in an infinity of ways. In connection with sparks from any possible source in a coal mine, it is probably possible to adduce most trustworthy evidence to show that such sparks have been displayed in contact with explosive gas without producing ignition. It is, however, impossible to accept such as of the least value without also including assured and detailed evidence as to the strength of the spark and the composition of the gases.

The safety lamp was designed by Sir Humphrey Davy, and was intended to provide a completely safe light for use in mines. The leading feature of this lamp is in the use of a wire gauze screen which was found to allow the passage of a certain amount of light while preventing the ignition of any surrounding atmosphere of dangerous gas. Moreover, the flame in this lamp when burning in a dangerous position shows a cap which, in the hands of an experienced man, gives useful warning of the danger. Practically all lamps now in use are derived from the original Davy, but many scores of inventors have meanwhile contributed to effect improvements, many of which are intended to circumvent the dangerous interference of workmen.

The use of a gauze screen in a safety lamp is based upon the conducting power of the metallic gauze with regard to heat, whereby a flame of moderate power is prevented from passing through the gauze. This may be shown by an ordinary erect gas burner. A horizontal sheet of gauze may be held at a distance of 2in. or 3in. above the burner and the gas turned on. The gas may be lighted either above or below the gauze, but the flame will not pass through the gauze.

Gauze screens cannot be used in connection with boiler flues, but similar cooling effect may often be in action along other lines to prevent accidents or to minimise the result. Such action must, however, be regarded as utterly unreliable, and it is imperative that every possible precaution should be adopted to ensure safety.

EFFECT OF SULPHUR IN RIVET STEEL.*

BY DR. J. S. UNGER.

SULPHUR in steel, whether justly or unjustly, is held responsible for its bad working. As a result the specifications covering the allowable amount of this element have been gradually lowered until in certain cases below 0·030 per cent. is the limit demanded. It is very difficult to reach this limit, and when reached there is grave doubt in the minds of many whether the quality of the steel has not suffered by the excessive purification required to produce such results. The following experiments were made to study the effect on the working and physical properties of rivet steel by gradually increasing the amount of sulphur until it had been raised to a point far above that usually found in such steel.

TABLE I.

Destruction Tests of Riveted Joints and Angles.

Sulphur content.	Riveted joints, shearing strength.	Riveted angles, breaking load.
	Lbs.	Lbs.
0·030	48,900	33,240
0·060	48,300	32,000
0·090	48,800	30,000
0·140	46,700	31,200
0·180	47,400	26,180

The steel used was basic open-hearth of carbon 0·09 per cent.; manganese, 0·43 per cent.; phosphorus, 0·012 per cent.; sulphur, 0·031 per cent. The sulphur content of certain ingots from this heat was increased progressively by adding weighed quantities of sulphur to these ingots, the additions being regulated to secure as near as possible a uniform increase of sulphur from one ingot to the next higher. The heating and rolling was done in the regular way and all ingots were treated alike. The finished $\frac{3}{4}$in. diam. rounds were alike in every particular as regards composition, heating, and rolling, except that they carried different amounts of sulphur. The rolled bars showed the following amounts of sulphur: 0·030 per cent., 0·060 per cent., 0·090 per cent., 0·140 per cent., 0·180 per cent.

Tests were made on three separate heats of steel with different sulphur contents. Tests were also made on bars riveted up at different driving temperatures. To determine what might be expected of the rivets when in actual service, a number of bars were riveted together and in addition a number of angles. These samples were then tested to destruction with the results shown in Table I. Both the tensile and shearing strengths decreased with the percentage of sulphur, the tensile nearly 13 per cent. and the shearing over 5 per cent. With the exception of the 0·090 sample in the shearing and of the 0·140 in the tensile tests, the diminution of strength was continuous.

The results of tensile and bending tests upon the rolled bars were as shown in Table II.

TABLE II.

Tensile Tests of $\frac{3}{4}$in. diam. Rounds as Rolled—0·09 Carbon.

Sulphur content.	Elastic limit, lbs. per sq. in.	Ultimate strength, lbs. per sq. in.	Elongation in 8in., per cent.	Reduction of area, per cent.
0·030	31,360	50,460	30·8	64·2
0·060	32,740	50,900	30·2	65·3
0·090	30,890	51,400	31·2	62·5
0·140	31,600	50,700	32·5	64·2
0·180	31,530	50,960	30·7	62·3

Tests were made on extra-long rivets under ordinary conditions to determine if one rivet head would stand as well as another. Nick bends were made, and the heads of the rivets were bent to see if any differences would be found in these cold bends, due to the varying sulphur contents. A similar set of tests was tried in which the rivets were heated to a driving heat (1,200° C.), then taken out of the fire and quenched in cold water to show the effect of drastic cooling from a high heat. A third set of tests was made on rivets that were heated to a blue heat (350° C.), then quenched in cold water.

The object in all these tests was to show whether the different treatments affected the rivets differently and whether the higher sulphur rivets were affected to a greater degree than the lower sulphur. The results are given in Table III. In addition to these tests, a double shearing test was made on the $\frac{3}{4}$in. rounds of each sulphur content in the ordinary condition. The shearing strength of each sample was as follows:—

Sulphur content.	Shearing strength in lbs., double shear.
0·030	33,430
0·060	33,060
0·090	34,000
0·140	33,100
0·180	34,000

So far as the author has been able to determine there does not appear, by working tests made on the finished rivet, to be any way of distinguishing between the quality of a rivet of 0·030 per cent. sulphur and one of 0·090 per cent. sulphur, if both have been subjected to the same conditions.

TABLE III.—*Tensile Tests of $\frac{3}{4}$in. Rivets in Ordinary Condition and Quenched.*

Sulphur content.	Elastic limit, lbs. per sq. in.			Ultimate strength, lbs. per sq. in.			Elongation in 8in., per cent.			Reduction of area, per cent.		
	a	b	c	a	b	c	a	b	c	a	b	c
0·030	34,010	44,100	32,700	51,740	69,700	50,630	34·2	8·1	23·0	70·2	62·5	61·5
0·160	32,820	44,450	31,060	51,050	71,160	50,400	34·6	9·8	25·0	70·4	62·7	59·4
0·090	37,480	54,690	33,430	51,620	76,600	50,140	36·0	7·6	32·8	67·3	53·7	59·2
0·140	34,320	49,380	32,060	50,320	70,520	49,500	33·7	11·1	32·0	67·1	58·3	60·8
0·180	33,340	43,730	32,200	51,050	67,850	50,510	37·4	10·6	34·0	65·8	54·8	60·4

(a) Ordinary condition. (b) Quenched in water from 1,200° C. (c) Quenched in water from 350° C.

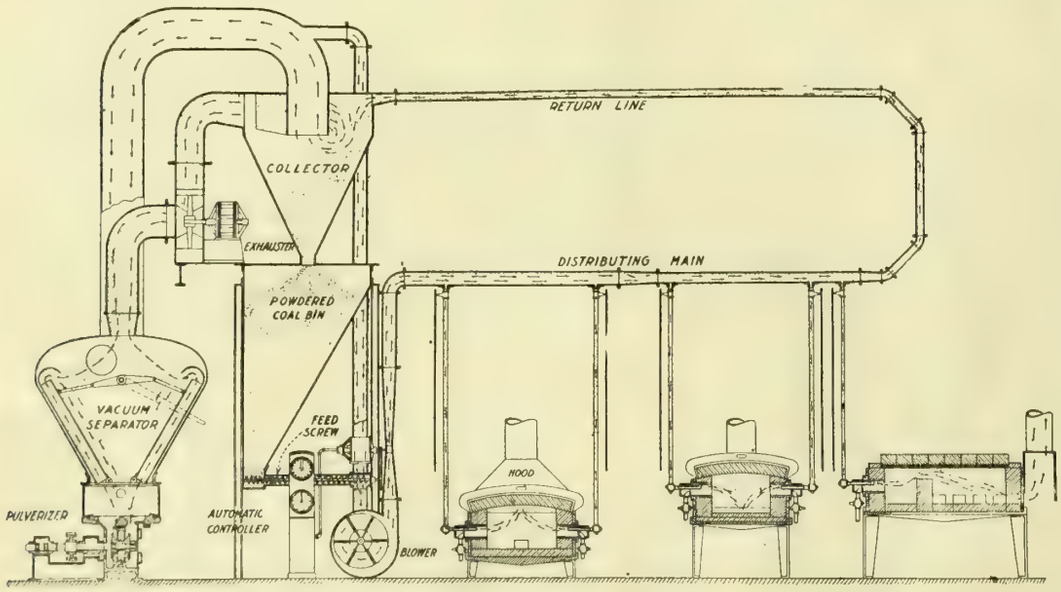
* Abstract of paper read before the American Boiler Manufacturers' Association, June 19th, 1916.

Lloyd's Shipbuilding Returns.—The returns compiled by Lloyd's Register of Shipping show that there were 440 merchant vessels of 1,540,218 tons gross under construction in the United Kingdom at the close of the quarter ended June 30th, 1916. The tonnage is about 117,000 tons more than that which was in hand at the end of last quarter, and about 33,000 tons more than the tonnage building 12 months ago.

HOLBECK SYSTEM OF POWDERED COAL BURNING.

WE are indebted to "The Iron Age" for the following particulars of the Holbeck system of powdered coal burning, as installed at the plant of the Middletown Car Company, of Middletown, Pa., U.S.A., where it is utilised for drop forge and other heating furnaces. The general scheme of the system is shown in the accompanying illustration. The powdered coal is distributed by being blown by means of an air current through a pipe, which makes a circuit around the plant, returning to the blower. There is a branch pipe to each furnace, which may be cut in and out as desired. The striking feature of the installation is that the powdered coal distributing main is 2,125ft. long. It contains 37 elbows and spans a craneway five times. Bituminous run of mine or slack coal is deposited in a track hopper and a reciprocating feeder feeds the coal into the hopper of a two-roll coal crusher. This delivers to a 24in. belt conveyor, which carries the coal to the boat of a bucket elevator, and by means of this and a 12in. spiral conveyor the coal is discharged into a 100-ton coal bunker.

The crushed or slack coal is taken, as required, from the coal bunker through a 6in. spiral conveyor to the hopper of an automatic scale, where it is weighed in 100lb. lots and passed on through another 6in. conveyor to the rotary coal dryer. This coal dryer employs a steel shell revolving at the rate of 5 revs. per minute. It is set at an inclination of about ¾in. to the foot. A slow fire is maintained in the fire chamber, placed at the delivery end. The products of combustion pass up through the dryer in direct contact with the coal, thus evaporating the moisture in the coal and carrying it in suspension and up the stack.



HOLBECK SYSTEM OF POWDERED COAL BURNING.

The coal is exposed to the heat for about 20 minutes. A 9in. spiral conveyor receives the coal as it is leaving the dryer and conveys it to a small coal storage bin placed between the pulverisers. The pulverisers are equipped with vacuum separators, so that it is necessary for the coal to be pulverised to a fineness where it will float in a partial vacuum before it can leave the pulverisers. The exhausters, indicated on the platform in the diagram, bring about the partial vacuum in the separators and exhaust the powdered coal from the separators and blow it into the collectors. The collectors extract the coal from the air and deposit it into the storage bin. The air returns to the pulverisers to be used over again. The coal dust is fed from the storage bin into the distributing system by a 6in. double flight conveyor.

The distributing system includes a blower furnishing air at 12ozs. pressure and a circuit of sheet metal piping for conveying throughout the works the coal dust in suspension in air. Branch pipes are run from the main pipe to the burners and furnaces. The amount of fuel to each burner is controlled by a valve in the branch pipe. Furnaces consuming as low as 10lbs. and as high as 400lbs. of coal per hour are served. The length of the distributing main has already been mentioned. A large flue, 600ft. long, connects many of the furnaces with a chimney stack, 6ft. diam. by 100ft. high, so that the gases and products of combustion may be taken out of the plant.

For drop forge work the best results are obtained by using a furnace with a combustion chamber, as shown in one of the sketches in the diagram cut. This chamber acts as a gas producer. The pulverised coal is almost instantly converted into a fixed gas and passes over the bridge wall, in the hot state, into the heating chamber where it meets additional air, thus burning and developing a high temperature. Forging heats, it is stated, are obtained inside of 20 minutes from the time of starting the fire, which is started by igniting a small piece of oiled waste and placing it in the burner and turning on the coal dust.

Another type of furnace shown is the under-fired furnace. In this case the combustion chamber is dispensed with and the stock introduced into the furnace from the top. For some work, such as drawing out or heating on the end only, this style of furnace gives very good service, but where it is necessary to heat the stock all over the combustion chamber furnace, it is stated, gives the best satisfaction. Mr. Holbeck has found that 10lbs. of pulverised coal is equivalent to 1 gall. of fuel oil.

CORROSION AND THE ELECTROCHEMIST.*

BY W. H. WALKER.

IN the valuable contribution of Dr. McCullom and his co-workers at the U.S. bureau of standards upon the corrosion of iron structures when buried in the ground, a terminology is employed which is very useful in discussing the damage occasioned by stray electric currents, as contrasted with that caused by the natural corrosion of the iron unaccelerated by an external electromotive force. But while it is logical to call the first type of corrosion "electrolytic," because induced by the flow of an impressed electric current, it is, however, illogical to describe the latter type a "self-corrosion" because of the unavoidable inference that it is not electrolytic, but is purely chemical in its nature. It may possibly be due to this lack of a clear conception of the mechanism of natural corrosion on the part of the electrical and mechanical engineers that they have displayed so little interest in the subject, and have so tardily availed themselves of the knowledge of the phenomena now at their disposal.

In dealing with problems of corrosion the engineer is satisfied if he can explain a phenomenon by stating "that a galvanic cell is set up." Thus a piece of coal in contact with an iron plate or a bit of mill scale on a pipe will cause a pit to form "because it sets up a galvanic cell." From a chemical point of view both the coke and the mill scale are perfectly inert; how then can they cause galvanic action—what role do they play in the solution of the iron which produces a pit?

Corrosion is an electrolytic phenomenon, and can be understood by electrical engineers on purely electro-chemical grounds. It takes place at ordinary temperatures only in the presence of water through the reaction

$$Fe + 2H^{\cdot} \rightarrow Fe^{\cdot\cdot} + 2H$$

This reaction means that a metallic iron atom electrically neutral interacts with two hydrogen ions present in the water. The hydrogen ions carry electrical charges, and the result is the production of an iron ion which takes up the two electrical charges from the hydrogen ions, also two atoms of hydrogen

* Paper read before the American Electrochemical Society.

are deposited. Energy is lost to the surroundings and appears as electricity and heat. The factors which influence the action may be segregated into five groups.

First, the solution pressure of the iron is constant for all samples of iron under constant conditions, but may be influenced by a number of agents. Thus the immunity of iron to corrosion in solutions of chromic acid is undoubtedly caused by the passivity of the iron, a thing which, whatever its true nature, is equivalent to lowering the electrolytic solution pressure of the metal. The impression of an external electromotive force may also be considered as equivalent to a change in solution pressure. This pressure may be either positive or negative in its direction. If the potential employed be generated mechanically, we speak of it as a stray current, but if electro-chemical in its origin it is described as the accelerating or retarding effect of other bodies. Thus iron, which itself is incapable of corrosion when embedded in concrete, is severely attacked if its solution pressure be sufficiently increased by having superimposed upon its own potential an external electromotive force due to stray currents. On the other hand, the potential of iron may be so depressed by an impressed electromotive force due, for example, to the solution pressure of zinc, that the iron in contact with zinc will not corrode.

The second factor in corrosion of iron is the number of hydrogen ions present. The greater the concentration the more rapid will be the corrosive action. Hence, if any substance forming hydrogen, such as carbonic acid or bicarbonate or sulphur dioxide or any acid-forming compound, be present, corrosion is accelerated. On the other hand, if an alkaline material such as soda ash or caustic soda be present, the number of hydrogen ions is decreased and corrosion is retarded. If enough hydroxyl, the active ion of an alkaline compound, be present, practically all of the hydrogen will disappear and corrosion will cease to exist.

The third determining factor in corrosion is the ease with which the hydrogen ion reaches the iron. For example, the alleged resistance of sheet steel containing small quantities of copper to corrosion when used as roofing is unquestionably due to the adherent nature of the film of oxide produced when corrosion starts. This film, as in the case of the aluminium oxide coat on metallic aluminium, insulates the metal and is believed to practically prevent further corrosion.

The fourth factor is the osmotic pressure of the iron ions. This is so small in any case that it is negligible; in the presence of oxygen the pressure is kept extremely low owing to the formation of insoluble iron hydroxide.

The fifth influence is deposition of the hydrogen and its removal by the depolarising action of oxygen. The accelerating action of metals such as platinum, copper, and lead, and materials such as coke and mill scale upon the corrosion of iron are undoubtedly due solely to the aid these bodies offer to the elimination of hydrogen produced by the corrosion reaction. This is due to the low overvoltage of hydrogen upon these substances and to the high catalytic action of these materials on the hydrogen-oxygen reaction by which the deposited hydrogen film is removed.

While in specific cases the corrosion of iron can be absolutely controlled by first one and then another of these factors, too little attention is generally paid to the influence exerted by the disposition of the hydrogen and its removal by the depolarising action of oxygen. The retarding action of the hydrogen film which is stable in the absence of oxygen and any acid-forming compound is so controlling that from this point of view, oxygen, or air, may be said to be the cause of corrosion. If oxygen be completely removed from boiler-feed water, the boilers will not pit or corrode. If oxygen be separated from the feed of ordinary hot water supply lines, the red-water plague and other corrosion troubles will be reduced to a minimum, if not entirely eliminated.

VALVE WITH FLEXIBLE SEATING.

A PATENT recently granted to Mr. R. R. Bevis, Vyner Road, Birkenhead, and Mr. J. H. Gibson, relates to valves having flexible seatings consisting of an annular thin metal disc, the outer part of which is held fixed between a facing on the valve seating and a facing on the ring secured to the valve seating by studs or bolts, and the inner part of which disc forms a flexible seating for the valve. The object is to provide a simple and cheap construction in which the machining and fitting required to provide an efficient valve is reduced, and in which the clearances are so reduced that the degree of flexure of the disc is limited to the minimum necessary to ensure a flexible jointing surface, the limitation of flexure preventing water hammer action and giving a more durable construction; further objects of the invention are, to facilitate the truing of the seatings by grinding, and the mechanical protection of the facings and seatings when the valve is removed for cleaning and repair. Fig. 1 is a diametral section through the valve casing, the valve seating, and part of the valve, and Fig. 2 is a similar view of a modification.

Referring to Fig. 1, A is the valve casing, B the valve seating, C the valve, D the guard ring, and E the flexible seating. The seating B is secured in position in the casing by the studs F, the collars of which fit recesses in the seating; these studs also serve to secure in position the guard ring D by means of which the flexible seating E is held in position on the fixed seating. The outer part of the flexible seating E is gripped between the facing G on the fixed seating and a facing H on the guard ring, and the latter is fixed concentrically relatively to the seating by a spigot on the fixed seating, which fits a corresponding recess in the guard ring. When the valve is in the closed position, as shown in Fig. 1,

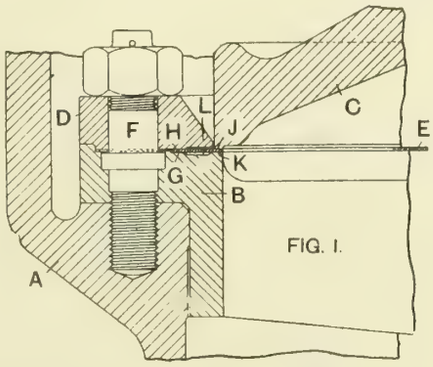


FIG. 1.

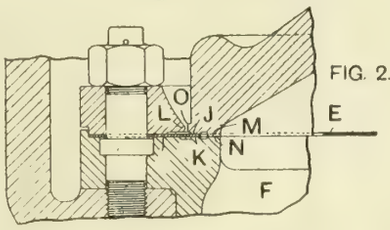


FIG. 2.

VALVES WITH FLEXIBLE SEATINGS.

the inner part of the flexible seating is forced by the annular facing J on the valve into contact with an annular facing K on the seating; when the valve is open the elasticity of the flexible seating causes it to leave the seating K, but the flexure of the seating is limited by the portion L of the guard ring which extends over the flexible seating, the flexure being limited to the minimum necessary to ensure a flexible jointing surface and being usually not more than 0·005in. It will be seen that the closing movement of the valve is limited by the facing K and the free edge of the flexible seating E interposed between this facing and the facing J on the valve.

In the modification illustrated in Fig. 2 an additional annular facing M is formed on the valve which, in the closed position, engages with an additional corresponding facing N, on the fixed seating; when the valve is closed the joint between M and N cuts off the flexible seating from the space F which in the case of a boiler stop valve communicates with the boiler interior. In fitting the valve, the facings J and M on the valve and the facings K and N on the seating, are so ground together that when the seating M makes contact with N in closing the valve, the flexible seating E is caused, by the joint action of the facing K and the facing J to make a flexible fluid-tight joint with the facing J. In order to protect the facing J on the valve from injury when the valve is removed and the facing edge is liable to be damaged when the valve is laid on its side, a projecting heading O is formed on the periphery of the valve; and in order to protect the flexible seating, the extension L of the guard ring is carried as far as possible over this seating.

TESTS OF ALUMINIUM BRONZE.*

BY W. M. CORSE AND C. F. COMSTOCK.

ALUMINIUM bronze subjected to a double-heat treatment of quenching followed by annealing, has its proportional limit raised without any great sacrifice of ductility, and at the same time is so improved in quality as to offer much greater resistance to alternating stresses. In this respect its qualities approach those of steel. These facts were determined by a series of tests in the Landgraf-Turner and White-Souther testing machines of a series of alloys, both with and without heat treatment.

In the Landgraf-Turner machine, a ⅜in. cylindrical specimen was bent backward and forward through a small angle by blows of a hammer, the number of blows required to produce fracture being automatically recorded. Tests of several alloys were made, with slots of ¾in. and 1in. between the hammers, the latter giving a less severe test. The character of the alloys and the average number of alternations of stress required for each of the specimens, without heat treatment, to produce failure is given in Table I.

The results of the tests on alloys Nos. 5 and 29 are fairly comparable with tests of steel rails and axles. Alloy No. 5 gave

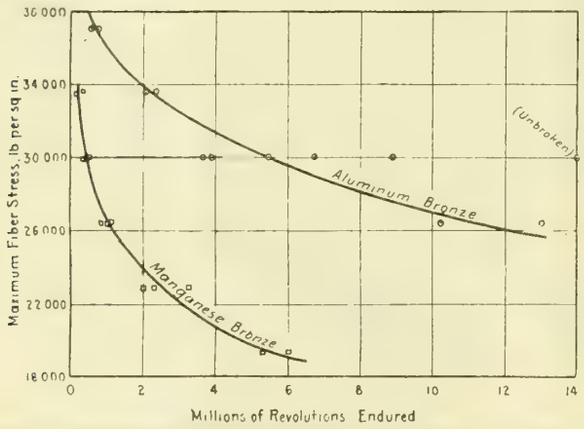


FIG. 1. STRESS ENDURANCE DIAGRAMS FOR WHITE-SOUTHER TESTS.

results far superior to steel, and had a remarkable endurance of severe alternating stresses.

TABLE I.—*Results of Landgraf-Turner Endurance Tests.*

Alloy No.	Name of Alloy.	Additional constituents.	Alternations to produce failure. Standard test. ¾in. slot.	Alternations to produce failure. Endurance test. ½in. slot.
		Per cent.		
3	Phosphor bronze	11 tin	75	1,437*
5	10 per cent. aluminium bronze	1 iron	4,485	5,220
		11 zinc 1 iron		
29	Manganese bronze	1 tin ½ Mn. ½ Al.	165	383

* 1in. slot between hammers.

The White-Souther machine more nearly reproduces the conditions of service. The specimen is revolved in the axis of a wheel at 1,300 revs. per min., the ends of the specimen being loaded with weights hanging constantly downward. The number of revolutions endured before fracture varies with the fibre stress and the character of the material. Tests were made on manganese-bronze and aluminium-bronze specimens, cast half in sand and half in a chill. The physical properties were as follows :—

	Manganese Bronze.	Aluminium Bronze.
Proportional limit, pounds per square inch..	29,200	20,460
Tensile strength, pounds per square inch ..	87,160	76,960
Elongation in 2in., per cent.	25·0	30·5
Reduction of area, per cent.	25·2	27·6

* Abstract of a paper presented to the American Society for Testing Materials, June 30th, 1916.

Tests were made at maximum fibre stresses of 33,000lbs., 30,000lbs., and 26,400lbs. per square inch for both materials, and in addition at a stress of 37,100lbs. per square inch for aluminium bronze and 22,900lbs. and 19,400lbs. per square inch for manganese bronze. The results of the tests are plotted in Fig. 1.

Aluminium bronze can be hardened by quenching from a high temperature. Tests were made to determine the proper quenching temperature of the No. 5 alloy, and also to determine the effect of a short air cooling prior to quenching. Test specimens about ½in. diam. were quenched from 700° C., 800° C., 900° C.,

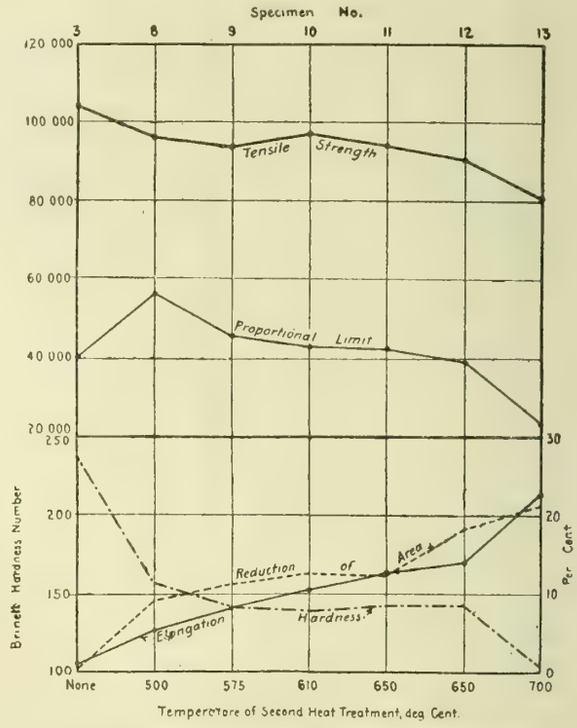


FIG. 2. PHYSICAL PROPERTIES OF SPECIMENS ANNEALED AFTER QUENCHING FROM 850° C.

and 1,000° C., and a temperature of 850° C. was adopted as the proper quenching heat. One of the specimens so quenched had the following physical properties :—

Proportional limit, pounds per square inch	39,800
Tensile strength, pounds per square inch	97,400
Elongation in 2in., per cent.	1·0
Reduction of area	None
Brinell hardness number.....	240

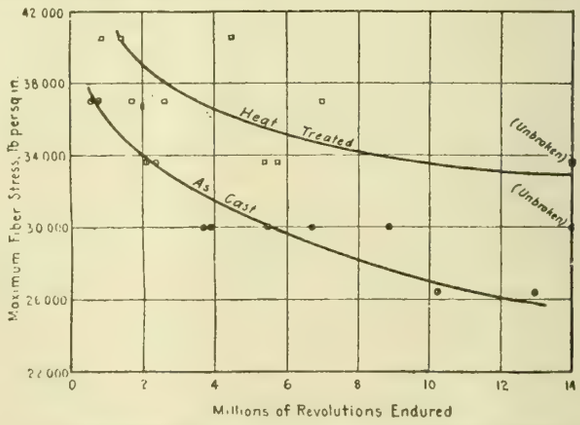


FIG. 3. RESISTANCE OF THE MATERIAL TO ALTERNATING STRESSES AFTER HEAT TREATMENT.

Tests made to determine the effect of air cooling before quenching indicated that this treatment lowers the elastic limit of the quenched material with only a slight increase in ductility. If not over 10 seconds elapses between the withdrawal of the piece from the furnace and its immersion in water, the quenching effect will not be lessened. Nothing is gained by intentional air cooling before quenching.

The effect of annealing after quenching was determined by a series of tests in which the specimens were heated to various annealing temperatures, and then cooled either in the air or in

the furnace. The specimens cooled in the furnace gave better results than the air-cooled ones, the speed of cooling apparently having an important effect on the physical properties. The results of the various annealing tests on the furnace-cooled specimens are plotted in Fig. 2.

To determine the effect of the double-heat treatment on larger castings, similar tests were carried out on rectangular blocks 2in. × 4in. × 9in., on a bar 2¼in. diam. and on two bars 1½in. diam. These were quenched and reheated to 650° C., excepting that the 1½in. bars were tempered at 600° C. and 630° C. respectively. The results given in Table II. indicate that the double-heat treatment improves large castings in about the same way as it does smaller ones, although the values finally obtained with large castings are not so good as those obtained with small ones.

Table II.—*Results of Tests on Specimens of larger size subjected to Double-heat Treatment.*

Original size.	Temperature of second treatment. Deg. C.	Proportional limit. Lbs. per sq. in.	Tensile strength. Lbs. per sq. in.	Elongation in 2in. Per cent.	Reduction of area. Per cent.
Inches.					
1½ diam.. ...	600	53,600	93,300	10·0	13·5
1½ diam.. ...	630	43,300	88,500	13·0	14·2
2¼ diam.. ...	650	34,600	74,000	14·5	17·6
2×4 block ..	650	40,800	85,100	12·5	15·7
2×4 block ..	650	39,700	78,200	9·5	15·0
2×4 block ..	650	40,200	74,700	9·0	13·5

The resistance of the material to alternating stresses after heat treatment is shown by Fig. 3.

SPELTER: ITS GRADES AND USES.*

BY G. C. STONE.

Spelter, like all commercial metal, contains impurities, but, unlike most other metals, none of these impurities are advantageous for any of these purposes for which it is used. The effects of these impurities on different products made from it vary greatly, hence the necessity for several grades differing in purity. Spelter is used for the following purposes, in quantities in the order mentioned: Galvanising, alloys, rolling, ornamental castings, and miscellaneous uses.

For ordinary galvanising the effect of the common impurities is not very great. Iron is objectionable as causing a loss in dross and in making the coating more brittle and liable to crack and peel off. Lead, up to the limit found in commercial spelter, has no serious effect, but is objectionable when present in large quantity, as it liquates in the bath and does not enter the coating, and is, therefore, wasted. Lead is usually worth less than zinc and the purchaser does not wish to pay for it at zinc prices.

The four higher grades of spelter are chiefly used for alloys and the specifications were principally made for the alloy makers and do not, in all cases, call for metal suitable for some of the other purposes for which it is used.

Aluminium.—In alloys, aluminium is frequently very injurious, 0·01 per cent. in many cases making brass useless for the purposes for which it is intended. In the few instances where its presence is desired, it is more satisfactory to add it directly than as a constituent of the spelter. The specifications (as proposed for the American Society for Testing Materials in 1915), therefore, require that the four higher grades of spelter shall be entirely free from aluminium.

Iron.—Iron is always present in spelter, but is very undesirable in brass and similar alloys, making them harder and greatly increasing the hardness due to cold working. The increased hardness is very objectionable, causing a greater consumption of power and endangering the rolling mills and drawing presses.

Lead.—Lead is very objectionable in some alloys and essential in others, and the main variation in the different grades of spelter is in the allowable amount of lead. High-grade spelter, which is used for alloys that are to be subjected to the most severe spinning and drawing operations, can be rejected if it contains over 0·07 per cent. of lead, as lead reduces the ductility of brass.

Intermediate spelter with a lead limit of 0·20 per cent. is used for alloys that do not have to undergo as severe treatment, and also very largely for alloys like manganese bronze that are used both cast and wrought.

Brass special has a lead limit of 0·60 per cent., and is mainly used for brasses where the maximum ductility is not required. The lead and iron are limited to 0·60 and 0·03 per cent. respectively, because brass made from such spelter is used for ordinary drawing, spinning, and forming work where the requirements are not especially severe.

Selected spelter carrying the maximum 0·80 per cent. of lead and 0·04 per cent. iron is used by brass manufacturers for making alloys to which lead is added in order to secure free-cutting qualities. Material of this kind is usually made into rods and heavy sheets for the manufacturing of small articles by turning, milling, and drilling operations. Such brass must contain sufficient lead to reduce the strength of the material and cause the chips to break easily.

Owing to the fact that brass is usually made in crucibles in small quantities, uniformity in the spelter is of the greatest importance. As lead segregates badly, and more markedly the higher the proportion, the lead limit of the average sample is made low enough to allow for this tendency without injurious effect on the product. Even when the brass manufacturer adds lead, he does so in known amounts and thus obtains a uniform alloy for the different pots, which would not be possible if all the lead needed were contained in the spelter.

Cadmium.—There is very little doubt that cadmium in zinc is very injurious for some of the purposes for which it is used, as it renders it harder and much more brittle. There is, however, considerable difference of opinion as to how far these undesirable properties persist in alloys made from zinc containing cadmium. The majority of the brass makers are of opinion that the high temperature of the brass pots cause so much of the cadmium to voltalise that the residual amount has very little deleterious effect. There is no doubt that large amounts of cadmium, say 1 or 2 per cent., make brass hard and brittle. We have no reliable information at present showing the effect of small amounts of cadmium on the alloys, and the evidence on this point is extremely conflicting. Cadmium, together with lead, seems to intensify the effect of the latter and also causes the brass to become more sensitive to the effect of overheating in the various annealing operations to which the wrought material is subjected.

Very little spelter is made containing as much cadmium as is allowed for intermediate and brass special, and the specifications, therefore, put practically no limit on cadmium except for high grade. Whatever the facts may be for alloys, it is certain that the amounts of cadmium allowed by the specifications are much greater than are permissible for other purposes for which zinc is used. The question of cadmium in the better grades is complicated by the fact that until the last year and a half practically all the high-grade and most of the intermediate spelter was made by one company from ores that are free from cadmium. The alloy makers have, therefore, had no extended experience with the effect of cadmium in the better grades of spelter, and during the last 18 months conditions have been so abnormal that it is difficult to draw conclusions.

High-grade spelter is very extensively used for galvanising telegraph and telephone wires which are required to stand sharp bending when making the "lineman's splice," as it has been found that if impure spelter is used, the coating cracks and peels off the joint. The only high-grade spelter that has been used for this purpose is entirely free from cadmium. Cadmium being the element most likely to cause this trouble, it is very doubtful whether metal containing as much as is allowed by the specifications (0·05 per cent.) would be suitable for this purpose.

For rolling, cadmium causes such severe cracking that metal containing much of it is not economical; but as practically all the zinc rolling mills produce their own spelter, this matter is within their own control and the specifications do not affect them.

For ornamental castings no spelter described by the specifications would be satisfactory. The high-grade is all right as far as lead and iron are concerned, but with the maximum cadmium allowed, it would be impossible to make castings of many of the common shapes.

* Presented before the American Society for Testing Materials.

FIRING SOFT COAL UNDER NAVAL BOILERS.*

BY WILLIAM L. DE BAUFRE.

COAL for naval use consists of from 90 to 95 per cent. of combustible matter and from 10 to 5 per cent. of ash. The fuel bed does not burn and sink in uniform layers. It is not of uniform porosity, and the greater quantity of air which naturally flows through a place of low resistance causes more rapid combustion there than in the denser portions of the bed, thus producing a "hole" in the fire. Few, if any, firemen are so skilled that they can keep these "holes" filled up and the fuel bed even simply by throwing the coal in the proper places with a shovel. It is therefore necessary to use a light hoe or rake to level the fire.

Also, with marine boilers, the yellow flames so fill the combustion space that it is practically impossible for the fireman to see the condition of the fire on the back half of the grate. It is therefore necessary for him to run a light hoe over the back of the fire to determine its thickness as a guide for coaling, in addition to filling up whatever "holes" may be present. However, the fires should not be disturbed more than necessary to accomplish the desired objects, and the more skilful a fireman is with the shovel the less will he need to disturb the fuel bed with a hoe or rake.

Some coals tend to cake and thus form a solid crust over the fire. Cracks start in this crust, through which the air passes, and crevices are formed by the crust burning at the edges of these cracks. Such crusts should not be allowed to form to any extent. While they can be largely prevented by firing smaller quantities of coal at more frequent intervals, they should also be kept broken up by the use of a light hoe. The hoe is likewise necessary when the coking method of firing is adopted. The coal is thrown on to the front part of the grate only and the volatile matter allowed to distil off, when the resulting coke is pushed back with the hoe over the fuel bed. This method of firing is not considered as conducive to good results, as the alternate or consecutive spreading method; that is, spreading the coal over the entire fire in the furnace doors alternately or consecutively.

Skill in the use of the shovel supplemented with the light hoe or rake will keep the top of the fuel bed in proper condition. Additional tools are necessary for the bottom of the fuel bed, especially with stationary grates. There are very few coals with an ash-fusing temperature so high that no clinkers are formed. The ashes that fall between the grate bars into the ashpit contain combustible matter in addition to the ash. The ash that remains above the grate, whether it fuses into clinkers or not, shuts off the air supply to the combustible above. A fire tool must therefore be employed to work this ash through the grate. If a hard clinker is formed which tends to stick to the grate, a sharp-pointed slice bar is required to pry it loose and break it up. But if the clinker formed is very friable or if simply ashes accumulate, a better tool for the purpose is a bar with a flat chisel-shaped end. A pricker bar may also be conveniently used under these conditions.

Neither the slice bar nor the pricker bar should be used indiscriminately, but should be moved back and forth over the grate where the ash or clinker is located just sufficiently to work it into the ashpit. The location of the accumulation of clinker or ash is indicated by the shadows or dark spots on the floor of the ashpan. Its removal is shown by the brightening of the dark spots. The brightening, however, will generally not occur as soon as the ash or clinker is removed, because the combustible above has been deadened by lack of air. Too much working of the slice bar will increase the loss of combustible in the ashes. Also, the fireman should not bear down on the slice bar to break up the fuel bed, as this will mix unburned coal with the ash and generally cause an excessive amount of clinker. Rocking grates are provided in stationary and locomotive practice to accomplish the same purpose of working the ash and clinker through the grate.

But even with the use of the slice bar, there are few coals in the burning of which the ash can all be worked through the grate. Clinkers will accumulate; and while they may be kept broken in many cases by the use of the slice bar, they must eventually be removed through the furnace door. The cleaning intervals adopted will depend upon the quantity and character of the clinkers, the variation of the load upon the boiler, the sequence of watches of the firemen, and the necessary routine of removing ashes from the ship.

For a thorough cleaning, the fire within the furnace door selected should be allowed to burn down slightly. At the time of cleaning, the combustible in the top of the fuel bed is winged over on to the fire at either side, using a hoe and a slice or special flat bar. The bottom of the fuel bed containing the clinkers is then hauled out of the furnace with a heavy hoe. The fire is now winged back on to the bare grates, levelled, and built up to standard thickness. Before cleaning, it is preferable to build up slightly the thickness of the fuel bed in the doors that are not cleaned. Also, under steady load conditions, it is better to clean the fire successively at regular periods unless the routine of the removal of clinkers and ashes prevents. Troublesome clinkers may be removed between the regular cleaning periods by using the familiar tool called the "devil's claw."

In working the top and bottom of the fuel bed, the fuel bed as a whole should not be disturbed more than necessary, in order to prevent as far as possible the formation of clinkers. Clinkers are due to the fusing together of particles of ash. The temperature at which the ash fuses depends mainly upon the constitution of the ash in the coal. When the fusing temperature is high, there is no trouble with clinkers, no matter how the fires are worked. With a low fusing point it is impossible to prevent the formation of troublesome clinkers, even with the most careful firing. But there are coals having a moderate fusing temperature of the ash which will give satisfactory results by careful firing. When the fuel bed is not disturbed, the ash accumulates only in the lower portion where the temperature is lower than in the upper portion of the fire. Also, in the lower portion of the fuel bed there is an oxidising atmosphere, while in certain upper portions there is a partially reducing atmosphere, and the fusing temperature of ash is less in a partially reducing than in an oxidising atmosphere.

Thick fires especially produce an atmosphere conducive to the formation of clinkers. The fires should therefore be carried as thin as is consistent with the draught and with good combustion, as measured by the constitution of the flue gases. The better the condition in which the fires are maintained, the thinner can they be carried with good combustion with the same draught.

Draught is the difference in pressure between the air in the boiler-room and the flue gases at the point considered. Furnace draught, for example, is the difference between boiler-room pressure and the pressure of the furnace gases just above the fire. Stack draught is the difference in pressure between the boiler-room and the flue gases at the base of the stack. The difference between the furnace draught and the stack draught is therefore the difference in pressure between the gases in the furnace and at the base of the stack. It is evident that this difference is equal to the frictional resistance overcome in forcing the gases through the passes and between the tubes of a water-tube boiler, for example. The furnace draught is equal to the frictional resistance encountered in forcing the air through the fuel bed. The former resistance will vary with the volume of the flue gases, but the latter will also be affected by the condition of the fuel bed.

To force the same quantity of air through the fuel bed a greater resistance is encountered if the fuel bed is thick, if a crust of unburnt coal is formed over the top, if ashes or clinkers clog up the grate at the bottom, or if the sizes of the coal particles in the middle of the fuel bed are such as to pack closely together into a dense mass. The last-mentioned cause of increased resistance depends only upon the character of the coal, but the first three are largely within the control of the fireman. Looked at in another way, if the fireman allows the coal to crust over the top, or if he allows clinkers and ashes to accumulate at the bottom, or if he allows the fire to become too thick, the air supply will be cut down unless "holes" are allowed to form in the fuel bed. These assumptions are based upon constant draught conditions; if the draught is raised the air quantity is increased, with the other conditions remaining constant.

In passing through the ashpit the air is somewhat heated

* From the Journal of the American Society of Naval Engineers.

by radiation. It is further heated in passing over the grate bars, which it thus keeps from being overheated. In the fuel bed it is still further heated until a sufficient temperature is reached to cause the oxygen to combine with the hydrogen in the fuel to form superheated steam (H_2O); with the sulphur to form sulphur dioxide (SO_2); and with the carbon to form carbon monoxide (CO), which then burns to carbon dioxide (CO_2). The nitrogen (N_2) of the air passes through unaffected, and oxygen (O_2) is found in the flue gases because an excess quantity of air over that theoretically required for combustion is always admitted.

Hence the flue gases contain superheated steam or moisture (H_2O), sulphur dioxide (SO_2), carbon dioxide (CO_2), carbon monoxide (CO), oxygen (O_2), and nitrogen (N_2). There may also be present particles of partly burned coal which will be deposited on the tubes and baffles as soot or carried out the stack as smoke. The flue gases may contain unburned hydrocarbons distilled from the coal if the air supply and temperature are not sufficient to cause their combustion.

The presence of superheated steam (H_2O) in the flue gases represents a loss. The loss is equal to the heat required to raise the temperature of the moisture in the air to the temperature in the stack, and the heat necessary to evaporate and superheat to stack temperature the moisture in the coal, that formed from the hydrogen present, the water added to the coal, and that put into the ashpit. The water added to the coal and the water put into the ashpit are the only items under the control of the fireman. Water may be added to coal to allay the dust in the fireroom or to reduce the loss of fine coal up the stack. No data are at hand to show the reduction in soot and smoke by adding water to the coal. Water should not be used in the ashpit unless it is necessary to keep the grate bars cool, to prevent troublesome warping of the ashpan, or to reduce clinker formation. Clinkers are sometimes reduced by blowing steam into the ashpit.

The amount of sulphur dioxide (SO_2) present simply depends upon the quantity of sulphur in the coal, and is small in coals for naval use. Sometimes a portion of the sulphur present remains in the ashes or clinkers as sulphur trioxide (SO_2).

The presence of unburned hydrocarbons depends partly upon the volume of the combustion space available, the manner of firing, and the proportion of volatile matter in the coal. If the combustion space is small, the hot gases containing unconsumed hydrocarbons are liable to reach the comparatively cold surfaces of the boiler and be cooled below the ignition temperature before they are completely burned. Also, if large quantities of coal are fired at a time, the large volumes of hydrocarbons distilled off are liable to lack sufficient air for combustion. If the coal contains a large percentage of volatile matter, the same condition is liable to obtain with careful firing. This fact is one reason why high-volatile coals are not suited for combustion in marine boilers where the combustion space is necessarily limited. From the fireman's standpoint coal should be fired in small quantities to prevent a loss due to unburned hydrocarbons. If necessary to increase the thickness of the fire, this should be done gradually and not by throwing a large quantity of fresh coal on the grate at one time.

With medium or low-volatile coal and fair firing, hydrocarbons are rarely present in the flue gases, even with the limited combustion space in marine boilers. It is therefore customary to omit their determination from the analyses of the flue gases. Neither the percentage of moisture (superheated steam) nor of sulphur dioxide is determined, but the analysis is limited to the measurement of the proportions by volume of carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2) present, the nitrogen (N_2) being found by difference. For routine conditions of service it is necessary to determine the percentage of CO_2 only as a guide to the condition of the fire. Recording CO_2 machines are built for this purpose.

The four quantities, CO_2, CO, O_2, and N_2, are closely related to the air supply. By perfect combustion with just the right quantity of air there would be in the flue gases about 20 per cent. of CO_2 and 80 per cent. of N_2 by volume. With air in excess of the theoretical quantity, O_2 is also present, the N_2 remaining approximately 80 per cent. of gas and the CO_2 and O_2 together being equal to about 20 per cent. The percentage of O_2 is an indication of the amount of excess air. Unless sufficient excess air is admitted, the flue gases will contain CO. The presence of CO represents a loss due to incomplete combustion, but the presence of O_2 with the correspondingly lower proportion of CO_2 also represents a loss due to excess air. When one loss is increased the other is decreased, and the combustion conditions should be adjusted until the sum of these two losses is a minimum. From experience at the Naval Engineering Experiment Station, it is believed that for naval boilers the minimum loss will correspond to a CO_2 percentage between 12 and 12·5 per cent.

The analysis of the flue gases is generally made at the base of the stack. Therefore, part of the excess air present is due to infiltration through the boiler casing. Before the efficiency of the combustion can be properly judged, care must be taken to ensure that the casing is airtight. Excess air is also admitted when the furnace doors are opened for coaling or levelling; hence these operations should be done quickly. However, undue haste should not prevent proper placing of the coal, and levelling for "holes" left in the fire during the intervals between the above operations will admit more excess air than the doors open for a few additional seconds.

The most economical results are obtained when the whole fuel bed is kept in a uniform condition. Then the desired percentages of carbon monoxide and oxygen and the corresponding percentage of carbon dioxide (CO_2) which has been found best by trial are kept constant by regulating the thickness of the fuel bed. If the CO_2 becomes low, it means that too much excess air is passing through the fuel bed, which is therefore too thin. The thickness should be built up gradually. If the fuel bed is too thick it should be allowed to burn down somewhat by firing slightly less coal until the desired CO_2 percentage is obtained.

The proper thickness will be between 4in. and 8in., depending upon the draught required to burn the requisite number of pounds of coal per square foot of grate surface per hour and also upon the clinkering properties of the coal. A clinkering coal should be burned with a thinner fire than a good coal. It may be impossible with a clinkering coal to attain a CO_2 percentage of 12 per cent. because the layer of clinker over the grate will shut off the flow of air through the fuel bed, and the consequent greater draught in the furnace will result in increased air leakage through fire doors and setting.

The stack draught should be regulated according to the load on the boiler. Regulation by the damper is better than regulation by opening or closing the ashpit doors because less excess air is liable to be drawn through the boiler casing by the former than by the latter method. When the load suddenly increases, the combustion is often intensified by the firemen cracking the fuel bed by lifting it slightly with the slice bar. With a coal that tends to clinker, this should be resorted to only in the last extremity and should be carefully done to prevent breaking up of the fire.

The furnace draught may be used as a guide in working the fires. If its value be noted for a given stack draught when the fires are in their normal condition, a rise in the furnace draught will denote an increase of the resistance through the fuel bed, and a drop will denote a decrease. The increase may be due to the fuel bed becoming thicker or clogged with ashes and clinkers at the bottom or covered with a coal crust at the top in case the coal cakes. The decrease will be due either to a thin fuel bed or to holes in the fire. The furnace draught also drops whenever the furnace doors are opened.

There is no practical method of firing, however, with which some non-uniformity in the fuel bed does not occur. When the doors are coaled in succession, part of the fire will be covered with fresh coal while the remainder is bright. This condition is considered more conducive to perfect combustion than if all doors were coaled at the same time, for in the former case the heat from the bright portion of the fire helps to raise to the ignition temperature the volatile matter distilled from the coal just thrown in the furnace. This method is also considered better than throwing the coal on the front part of the grate, allowing it to coke, and then pushing it back over the whole grate.

The coaling should be done as nearly uniformly as possible, throwing on the same number of shovelfuls each time. The firing intervals should be selected so that each charge will not exceed 30lbs. to 50lbs. of coal (three to five shovelfuls).

Then the fireman can slightly increase or decrease the quantity as he finds his fires getting thinner or thicker. He will sometimes find the fire within one door consuming more coal than in the other doors. This condition can generally be traced to a thinner fire, which allows a larger quantity of air to pass through to intensify the combustion. If necessary the fire in that door should be kept a little thicker than in the other doors to equalise the rates of combustion.

If the coal is fired in small quantities at uniform intervals, and the fires are otherwise maintained in good condition, the smoke formed will have the minimum density for the boiler in use and the coal fired. The coal particles carried along by the gases are therefore cooled by the heating surface below the ignition temperature before they have time to burn completely. Smoke consequently forms. With high-volatile coals a dense black smoke is continually emitted from the stack, but with medium or low-volatile coals smoke should occur for a few seconds only after coaling.

Based upon the foregoing considerations, there has been adopted the following method of firing coal during evaporative tests at the Naval Engineering Experiment Station: The draught at the base of the stack is maintained constant at 0·750in. water, for this stack draught has been found to burn about 25lbs. of coal per square foot of grate surface per hour, with a furnace draught of about 0·3in. water. The boiler is allowed to generate as much steam as it can under a steam pressure of 300lbs. gauge, which is kept constant by regulating a throttle valve on a bleeder line through which a portion of the steam generated is discharged to a surface condenser. A firing interval of five minutes has been selected, resulting in a charge of about 40lbs. of coal being fired at a time. The furnace has three doors, so that the interval between firing the successive doors is 1 min. 40 secs. The fires are levelled at 5-minute intervals, and in the order in which the doors are coaled: When door No. 1 is coaled, door No. 2 is levelled; when door No. 2 is coaled, door No. 3 is levelled; and when door No. 3 is coaled, door No. 1 is levelled. The slice bar is used at hourly intervals, but only if dark spots appear in the ashpan. The cleaning interval is 12 hours. With three furnace doors and firemen's watches of four hours on and eight hours off, the interval results in the cleaning of a fire each watch.

Samples of the flue gases from the base of the stack are collected during half-hourly intervals and immediately analysed for CO_2, O_2, and CO. Analyses for hydrocarbons are made several times during each test, but no appreciable percentages have been found with coals tested to date. A CO_2 machine is also in continuous operation. The firemen are directed to so regulate the thickness of the fires as to maintain the constant percentage of CO_2 which yields the best results. This percentage has been found to be in general about 12 to 12·5 per cent., corresponding to a fuel-bed thickness of approximately 6in. Leakage of air through the casing is prevented by carefully plastering before the test all possible cracks with asbestos cement.

METAL QUOTATIONS.

TUESDAY, AUGUST 22ND.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled	1/3¾ per lb.
,, tubes (brazed)	1/5 ,,
,, ,, (solid drawn)	1/3 ,,
,, ,, wire	1/2⅞ ,,
Copper, Standard	£111/–/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£31/5/– ,,
,, Foreign (soft)	£30/–/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	31 9/16d. per oz.
Spelter (American)	£47/–/– per ton.
Tin, block	£169/5/– per ton.
Tin plates, I.C.	32/– per box.
Zinc sheets	£72 per ton.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1914.

Methods of and apparatus for washing coal. Habets. 15689.

1915.

Compressed-air brakes. Chapsal & Saillot. 3579.
Rock hammer drills. Kewley & Corner. 5451.
Concentration of ores. Howard, Wood, and Minerals Separation, Ltd. 8263.
Apparatus for stopping trains independently of drivers and for actuating signals on trains. Nevitt. 9275.
Ship-propulsion installations. Parsons, Walker, Cook, and Douglas. 10824.
Speed indicators or recorders. Gill & Chaviara. 11110.
Jib cranes. Priestman. 11343.
Valve mechanism for internal-combustion and other engines. Riley. 11933.
Valve. Jones. 12790.
Valves. Blakeborough & Broadhead. 13358.
Means for atomising paraffin for use in internal-combustion engines. Sweetser. 13373.
Melting of iron and steel. Rincker. 14215.
Reducing valves. Jacquel. 14546.
Screw-cutting taps. Coventry Ordnance Works, Ltd., and Bates. 15820.
Pressure reducing valves. Bailey & Bailey. 16839.
Dry process and an apparatus for purifying blastfurnace gases. Dortmunder Bruckenbau C. H. Jucho, and Haring. 17081.
Propellers for aircraft. Judge, and Varioplane Company. 17434.

1916.

Sprayers and injectors for liquid fuels. Marks, E. C. R. 1484.
Manufacture of hollow metal ingots. Bedford, R. A. 1717.
Sheet metal split pulleys. Haddan, R. 2967.
Internal-combustion engine valve gear and mechanism. Barker, T. N. 3584.
Taps or valves. Ford, A. P. 4132.
Method of and means for balancing split belt pulleys with exchangeable rims. Nyberg, C. S. 4883.
Tubes for radiators. Turney, G. W. 5806.
Carburetting systems of internal-combustion engines. King, C. F. L. 6560.

ELECTRICAL, 1914.

Electro-magnetic friction clutches. Bing. 15690.

1915.

Electrical heater. Kerr. 8537.
Starting and synchronising of dynamos. British Thomson Houston Company, and Whitaker. 11321.
Operating rotary converters and other alternating current machinery. Railing & Garrard. 13934.
Magneto electric machines for ignition in internal combustion engines. Conner. 14993.
Sparking arrangements for electric ignition devices. Ireland. 15873.
Construction of sparking plug for internal-combustion engines. Heath. 17910.

1916.

Systems for the protection of electric cables in the event of external damage. Beaver, C. J., and Claremont, E. A. 3707.
Telephone instruments. Petithory, E. A. 5061.

A Good Use for Old Tracing Cloth.—One of the minor directions in which engineers can help the war is by collecting all their old cloth tracings or unused tracing cloth and sending it to Lieut. R. D. T. Jones, R.E., Ministry of Munitions, Explosives Department, Storey's Gate, Westminster. The cloth, when boiled, washed, and sterilised, makes excellent bandages, pillow cases, &c., for the wounded—things that are still badly needed. Engineers need have no fear that their designs will be copied, because all the tracings are handed to a responsible person to be treated. Many firms have already helped in this way, and it is hoped that many more will do so. There are few works that do not destroy dozens of yards of tracing linen a year, and now that this excellent use for the waste material is pointed out to them we feel sure they will respond to Lieut. Jones's request.

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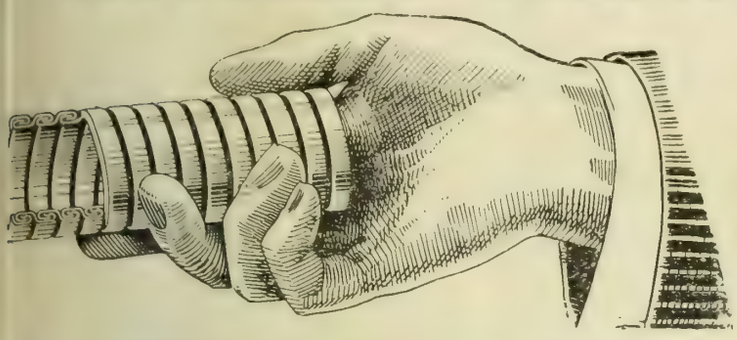

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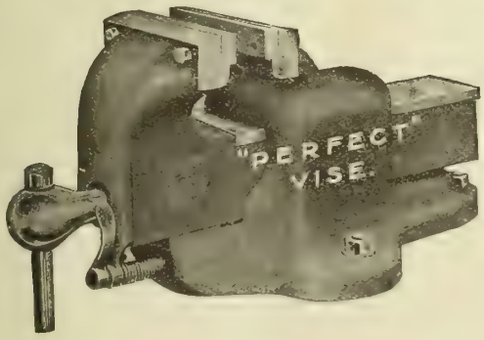

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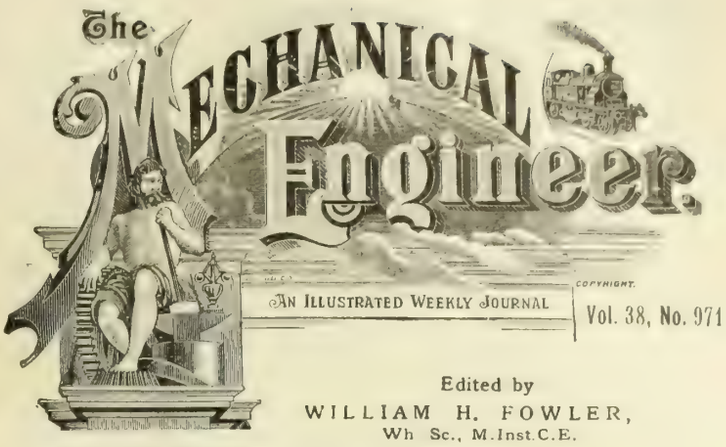

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Industrial Efficiency.

DISCUSSIONS of social problems likely to arise after the war are very much to the fore just now, and as these are many and serious, and will need careful consideration to reach a solution, a discussion of them, even whilst national energies are almost wholly absorbed in the titanic struggle, cannot be called inopportune. The root factor underlying all the problems will be how to make good the appalling waste and destruction that has occurred; how to restore to populations of enfeebled nations the standards of comfort enjoyed in pre-war-time peace days; how to replenish the depleted stores of capital; how to repair the crippled productive powers of industry and enable it to bear the extra load of taxation that will inevitably be laid on the back of every belligerent nation. No universal panacea will meet the coming difficulties. Reforms cutting deep into all past beliefs and prejudices will be necessary. Education must be wider and be in closer touch with the actualities of life. No longer must the phrase "a liberal education" imply a familiarity with dead languages and an ignorance of living ones, an ability to quote classic authors and an ignorance of the rudiments of science, a familiarity with manners and etiquette and an ignorance of the ways in which the masses toil and earn their daily bread. Older methods of training must be discarded. The acquisition of knowledge must be a means to an end, and that end increase in industrial efficiency. To it there will be no short or pleasant roads. Hard work will be the essential feature of all of them. People have come to see that wealth cannot be created by political juggling, but only by hard work, that shot and shell and safety can only come out of strenuous endeavour, and that any measure of comfort or happiness to be enjoyed in the future will depend upon its continuance by each and all. Limitation of output, "ca

canny" restriction of employment, demarcation of labour, the caste system that forbids a mason to handle a brick or a bricklayer to touch a stone, along with all other tyrannical developments of socialistic trade unionism, must be abolished. The extent to which the more aggressive sections were prepared to push these doctrines during the time of the nation's distress in the early days of the war are not likely to be forgotten by the public when it is over. Notwithstanding the promises extracted from political parties that these so-called "rights and privileges" should be restored, we venture to think they will not again be tolerated. Their revival would in no way diminish the burden all must bear or alleviate the lot of those who would reimpose them. The last 12 months has afforded a vivid object-lesson of what can be done in our workshops with female and unskilled labour under the stimulus of patriotism untrammelled by the fetters of so-called "skilled" trade union labour, and what high rates of wages "unskilled," or we prefer to say quickly trained, labour can earn under such conditions. It is to the advantage of the whole mass of workers, "skilled" or "unskilled," that monopoly restrictions, which have been so blindly worshipped by a section of them, should be abolished. Equally futile, in our opinion, as a means of increasing industrial efficiency would be any system of nationalising industries. It is easy, of course, to point to the present condition of the working of our railways as an example, but in the absence of all data as to cost, this semi-military measure provides no adequate illustration, and those who glibly suggest that the working of collieries, the shipping industry, and in fact all great national enterprises, should be run on similar lines, have a very imperfect conception of the complexity of the problems that such a transformation would involve, and overlook the fundamental fact that change of ownership in no way alters the economic relations between the employer and the employed, or the prejudices and heartburnings that inevitably arise where human beings are called upon to put forth organised and combined effort.

NOTES ON ELECTRIC RAILWAY TRACK LEAKAGE.

TECHNOLOGIC Paper No 75, issued by the U.S. Bureau of Standards, entitled "Notes on Electric Railway Track Leakage," by G. H. Ahlborn, deals with data obtained as a part of the general investigation of electrolysis carried on by the Bureau of Standards. The physical characteristics of three suburban and interurban lines are given, and tests, conducted with the cars off the line and the concentrated load at the extreme end, described. The first line is constructed with double tracks, the rails being embedded in the street surface for most of the length, which is 5·5 miles. The road bed of this line is quite well drained, and the elevation is between 200ft. and 300ft. The total leakage from this track, including that escaping from the terminal networks, is about 28 per cent. of the total current impressed, which was 300 amps., or the leakage is 84 amps. Calculations involving the distribution of leakage along the line show that the resistance of the track is increased 15 per cent. because of rail joints, which is not excessive, since several isolated high-resistance joints increase the resistance, and the joints on the average are good. The average road-bed resistance for 1,000ft. of single track is about 1·76 ohms.

The second line tested is single track, about 11 miles long, with the rails practically clear of ground. The elevation of this line is about 125ft. and the soil is chiefly sand and gravel, so that it drains readily. The leakage from this line amounted to 47 per cent., or, with the 150 amps. impressed, about 70 amps. This is not as excessive as might seem in comparison with the first line, because the overall potential drop required to force the current through this line was three times as great. However, the track was not in good condition, the joints increasing the resistance over that of the solid rail by 40 per cent. The resistance to ground was unusually high, being about 14·57 ohms for 1,000ft., or 2·75 ohms for one mile.

The third line was single track, about 6·5 miles long, with the rails generally clear of soil. However, the elevation was very low, being about 10ft. above sea level on the average, and the soil was impregnated with salt water from the surrounding marshes. The total current impressed was 205 amps., and of this amount only 14 amps. remained on the track throughout its entire length, or the leakage was 93 per cent. Here, again, the overall potential is high, being 87 volts, but the track was in very bad condition, the joints having increased the effective resistance to nearly 16 times what it would have been with continuous rails. For considerable distances one rail carried the entire current, and this rail had many high-resistance joints. The leakage resistance was low, being 1·8 ohms for 1,000ft., or about 0·34 ohm for one mile.

The report emphasizes the importance of maintaining as high resistance to ground as is feasible, but especially of having a high standard of rail bonding and cross bonding on all lines.

MECHANICAL STOKERS ON LOCOMOTIVES.

AT the convention of the American Railway Master Mechanics Association some interesting figures relating to the use of mechanical stokers on locomotives in the States were presented. The figures show that up to April 1st, 1916, no less than 1,418 stokers of the four leading types had been applied as follows: Street, 866; Crawford, 413; Hanna, 39; Standards, 100. Reference was also made to the Locomotive Stoker Company's newly-introduced duplex stoker, which has for its object the conservation and efficient utilisation of a greater amount of the finer produce in the fuel heretofore subject to more or less loss with any of the scatter type machines. One of these machines has been applied to a Mallet engine on the Norfolk and Western Railway, and another to a locomotive of a similar type on the Chesapeake and Ohio Railway, and a third is on order for the Chicago, Burlington, and Quincy Railroad.

TRANSMISSION GEAR FOR ELECTRIC LOCOMOTIVES.

A COMMITTEE report presented at the annual convention of the American Railway Master Mechanics Association, referring to the means of transmitting the power from the motor to the drivers of electric locomotives, including cost of repairs and losses by friction, states that the designs without gears or transmission rods are the most efficient for train speeds exceeding 45 to 50 miles an hour. Below these speeds the committee recommend the gear and pinion as being probably the most efficient. The jack shaft, according to the report, has so far been found not entirely satisfactory, as it appreciably increases internal friction, and it has been found difficult to keep it from pounding and running hot. Quill springs have given rather more trouble than is desirable by breaking or becoming unseated. Where gears are used, some design of spring or flexible gear will probably be found desirable for steam railroad electrification.

Iron and Steel Institute.—The autumn meeting of this Institute will be held, by kind permission, at the Institution of Civil Engineers, Great George Street, Westminster, on Thursday and Friday, September 21st and 22nd, 1916, commencing at 10-30 a.m. on the 21st and at 10 a.m. on the 22nd. The following is the list of papers that are expected to be submitted for reading and discussion: (1) "Some Properties of Ingots," by H. Brearley; (2) "Influence of Heat-treatment on the Thermo-electric Properties and Specific Resistance of Carbon Steels," by Prof. E. D. Campbell; (3) "Heat Treatment of Eutectoid Carbon Steels," by Dr. H. M. Howe and A. G. Levy; (4) "Steel Ingot Defects," by J. N. Kilby; (5) "Manganese Ores of the Bukowina, Austria," by Herbert K. Scott; (6) "Influence of Elements on the Properties of Steel," by Dr. J. E. Stead, F.R.S.; (7) "Notes on (*a*) Nickel Steel Scale, (*b*) On the Reduction of Solid Nickel and Copper Oxides by Solid Iron, (*c*) On Effect of Blastfurnace Gases on Wrought Iron," by Dr. J. E. Stead, F.R.S.; (8) "Use of Meteoric Iron by Primitive Man," by G. F. Zimmer.

THE USE OF CRUDE OIL FOR CUPOLA MELTING.*

BY BRADLEY STOUGHTON.

THE object of the oil cupola process is to replace coke melting with oil melting. The cupola is chosen as the furnace because many years' experience have shown that this is the most efficient and cheapest known furnace for melting. Three principles are essential to the success of this process: The first is preventing the iron in the cupola from matting together when it reaches the plastic stage which precedes melting. Cupola melting with oil or coke has been tried several times by merely filling the cupola with iron and then applying the flame at the lower part. In each case the result has been to entirely clog the cupola, because the iron, as soon as it becomes plastic, mats together by the weight of the metal above. It has been suggested that the cupola might be kept open and pervious to the heat by providing a bed of refractory metal in the lower part. Upon this bed the iron would rest.

There are, however, two important objections to this: The first is that the melted iron-oxide and slag attack the firebrick and in time cause it to be joined together at the edges, making it impossible to dump the cupola and also making it impossible to use the same refractory material the second time, besides reducing the porosity of the bed. Those who are familiar with the cutting-out of the cupola lining at the melting zone will appreciate the difficulties that would be experienced with a bed of refractory material over which the melted iron oxide would flow.

The second difficulty of using firebrick to keep the charge open is that it would be necessary for the firebrick to be mixed with the iron in the upper part of the cupola. Otherwise, the matting together, instead of taking place at the melting zone, would take place at some point higher up. If, however, every charge of iron had to contain a certain proportion of refractory material, the result would be that the bed in the bottom of the cupola would be built-up to such a point that the iron would be raised above the melting zone.

It is possible that a bed consisting partly of firebrick and partly of a material which would be consumed might give more economical results than the bed now used in the oil cupolas, which consists entirely of coke.

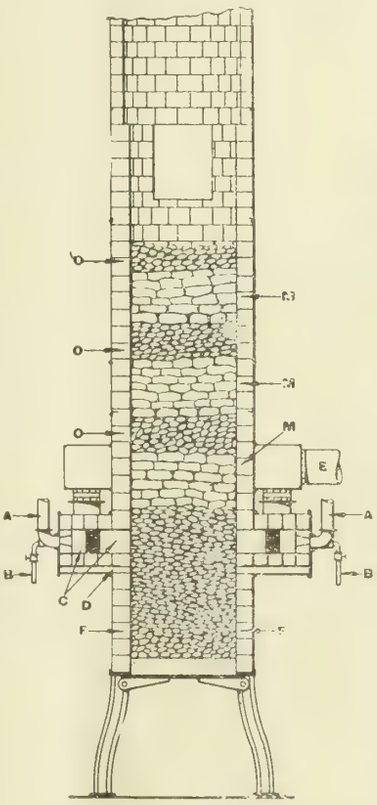
The second basic principle which it is necessary to recognise to secure success in oil melting is that crude oil cannot be efficiently burned unless some extraneous source of heat other than the combustion of the oil itself contributes to the flame. It is well known that an oil flame deposits graphite in large quantities, this graphite being due to the incomplete combustion of the oil. The use of preheated air is one means of supplying heat from an extraneous source and this results, in the open-hearth furnace, for example, in a great reduction of the amount of graphite deposited.

In the oil cupola, however, we are using a bed of coke and burning a very small amount of this bed in order to furnish that supplementary heat which is necessary to ensure the complete combustion of the oil. The amount of bed which is burned is only a fraction of that burned in the ordinary coke melting process, since the heat for melting is obtained, in the oil cupola, chiefly from the combustion of oil. Merely enough coke is burned to maintain the bed in an incandescent state, and to supply a small amount of heat for promoting the complete combustion of the oil. This principle, which may seem unimportant and trivial, is of very great importance, and is essential to the success of the process.

By burning a very small amount of the bed, it makes it possible to mix a sufficient amount of coke with the charges of iron to maintain the shaft of the cupola in a porous condition, and to prevent matting together of the material in that location. The coke used for this purpose ultimately finds its way down and replaces the coke burned from the bed.

The third principle upon which the success of the oil cupola process depends is the means for controlling the combustion of the oil and coke. We have discovered that, if air be mixed with atomised oil and blown upon a bed of red hot coke, the air will unite only with the oil, unless we supply more than enough air, when the additional air will burn the coke. In other words, the air unites by preference with the oil and will not burn any coke until there is an excess of air. This action is so well marked that one may direct a flame of burning oil upon a bed of red hot coke and actually put out the coke fire therewith, provided the oil flame does not contain an excess of air. The establishment of this principle enables one to absolutely control the combustion of the oil and coke by controlling the amount of air admitted. It is possible to do this by admitting a regulated excess of air with the oil flame but we prefer to maintain the oil and air in the flame in such proportions as will give complete combustion of the oil and then to burn the necessary small amount of coke by an independent admission of air.

For example, in the accompanying illustration, the oil and air are admitted through the pipes B and A into the ignition chamber C. The oil flame is started in this ignition chamber and enters the cupola in contact with the coke bed F. This coke bed is maintained in an incandescent state by an independent supply of air admitted through the tuyeres D, which are underneath the ignition chambers C. The peep holes at the end of the tuyeres D and the ignition chamber C enable one to observe the combustion of oil and coke, and independent valves connected with each of the different pipes enable the air to be adjusted to give perfect combustion of oil in the ignition chamber and the necessary amount of combustion of the coke through the tuyeres D. It is obviously desirable to have the minimum possible consumption of coke which will maintain the bed in an incandescent state, and this is accomplished by adjusting the valves connected with the tuyeres D.



CROSS SECTION OF OIL FIRED CUPOLA

A Air for Atomising Oil; B Oil Supply Pipe; C Ignition Chamber; D Tuyere for admitting Air for Combustion of Coke; E Main Blast Pipe; F Coke Bed; M Charges of Iron for Melting; O Supplementary Coke Charges.

The cupola is first filled with coke up to the melting zone, and this coke is brought to a state of incandescence in the usual way. The amount of coke used and the method of getting it red hot is the same in the oil process as in the usual coke process. On top of the bed then is placed the first charge of iron, which also is the same size as in coke melting; then comes a layer of coke which is only one-quarter the amount ordinarily used. On top of this comes another layer of iron of the usual weight, then a layer of coke of one-quarter the usual size, &c. The coke bed is kept red hot at all times by its own combustion, but that combustion is very much less than the coke combustion in the ordinary cupola, because we do not want that heat to melt the iron; we merely want sufficient heat to maintain the bed at a bright red colour. In practice, we find that the amount of coke burned is generally one-quarter of the amount generally burned by the ordinary process and, therefore, the layers of coke coming down from above are just sufficient to replenish this bed and maintain it as in the ordinary cupola process.

The oil is atomised into ignition chambers surrounding the cupola, and is there mixed with air for its combustion. The flame from the burning oil enters the cupola and comes in contact with the bed of coke by which its combustion is hastened and completed. The result is an intensely hot oil flame by which the bulk of the melting is done.

The operation is similar to the ordinary coke melting operation, the principal difference being that the temperature is under better control by means of controlling the oil and air admitted. When once adjusted, the oil flames need very little further attention. The results obtained with an oil fired cupola were given in our issue of February 18th last (see page 122, Vol. XXXVII.).

* Abstract of paper presented before the Pittsburg Foundrymen's Association.

SOME REFINEMENTS OF MECHANICAL SCIENCE.*

BY AMBROSE SWASEY.

THE division of the circle and the measurement of angles has ever been among the unsolved problems of the astronomer, yet in the instruments used by him circles have formed a most important part. Long before the telescope was invented, Tycho Brahe, the Danish astronomer, "the founder of modern astronomy," constructed for his observatory instruments of various kinds having graduated circles and arcs of circles. His instruments for the most part were improvements on those used by Arabian astronomers in the eighth and ninth centuries, and these, in turn, were copied after similar instruments used by the Greeks and Egyptians a thousand years previous, and it is supposed that such instruments were used by the Chinese at an even earlier period, so that graduated circles have come down to us from the far-off ages.

The first circular dividing engine was made in 1740 by Henry Hindley, of York, England, for cutting the teeth of clock wheels, and it is interesting to note that in the same year Huntsmann, another clockmaker, of Sheffield, invented the process of making crucible steel, that he might have a metal suitable for the springs of his clocks. Of the several engines constructed later, the one most successful and representing the greatest progress was that made by Ramsden, in 1777. This engine, automatic in its movements, was made especially for graduating circles, and because of the great precision with which he divided the circles of the instruments used by the Government, the Board of Longitude awarded him the sum of £615. A further and most potent recognition of the excellence of his work lies in the fact that all subsequent circular dividing engines have followed closely the same general principles of construction embodied in the Ramsden engine.

Many excellent dividing engines have been made that are quite sufficient in point of accuracy for the work for which they were intended, but the perfection required in the graduation of circles for astronomical instruments is such that it has been found to be one of the most difficult of all mechanical problems to make an engine to meet such requirements. In such an engine the chief essential is that the spindle carrying the master-plate shall be as nearly round and as closely fitted in its bearings as is possible, for the degree of excellence with which that work is done determines how closely a circle can be divided.

It seems almost incredible that a well-lubricated spindle of four inches in diameter at its largest part and tapering three-quarters of an inch to the foot can be made so nearly round and so closely fitted in its bearing that a movement of one-thousandth of an inch in or out of its bearings will in one case cause it to turn with difficulty, and in the other with perfect freedom, yet this has been found to be within the limits of mechanical refinements.

The greatest accuracy thus far attained in such engines is one second of arc, which arc, with a radius of three miles, equals one inch, and at twenty inches, which is the radius of the silver ring upon which the graduations on the master-plate are made, a line one-thousandth of an inch in width is equal to twelve seconds of arc, or twelve times the accumulated errors of any number of divisions, or twenty times the greatest error of any single division.

In automatically graduating a circle, it has been found to be impracticable to cut more than six lines in a minute, and it requires about thirty-three hours to divide a circle into two-minute spaces. As with the running of the finest clocks, the best results can only be obtained when the engine is surrounded with every favourable condition possible. Instead of the large circles and sectors used by the ancients, they have been made smaller in diameter as the methods for graduating have been improved, until those of the more modern instruments are seldom more than thirty inches, and some of the latest meridian instruments have circles of but 25in.

A 25in. circle read with a microscope having a power of 40 would be equivalent to a circle of about 80ft. in diameter, and a single second of arc as seen through the microscope would be equal to 0·0024 of an inch, a quantity easily subdivided.

Step by step from the methods of the Arabian astronomers to the time of Tycho Brahe and on down to the present day, improvements in the instruments and methods for the measurement of angles have been going on, until astronomers can measure double stars with a separation of one second of arc, and within less than one second they can define their positions in the heavens.

In the realm of the measurements of minute linear distances, and the perfection of curved and flat surfaces, the refinements are even greater than those pertaining to the measurement of time and of angles. Most important in the linear dividing engine is the screw, and although much had been accomplished in bringing such engines to a high degree of excellence, it was for Prof. Rowland to make an engine which has a practically perfect screw; and without doubt it is in all respects the nearest perfect of all the mechanisms that have been employed for ruling lines exactly parallel and equally spaced. The Rowland engine was made especially for ruling diffraction gratings which are made of speculum metal, and with it a metal surface has been ruled with 160,000 lines, there being about 29,000 to the inch, and as many as 43,000 lines to the inch have been ruled.

The gratings mostly used have from 14,000 to 20,000 lines to the inch, and with such exactness is the cutting tool moved by the screw that the greatest error in the ruling does not exceed one millionth of an inch. The production of these gratings, which has enabled the physicist in his study of the spectrum to enter fields of research before unknown, has not only called for the highest degree of perfection ever attained in the spacing of linear distances, but it has also called for a refinement most difficult in the optical surfaces upon which the lines are ruled. To Mr. Brashear was given the problem of producing such surfaces, and notwithstanding the many difficulties encountered in working and refining the speculum metal plates, he has made many hundred plates with surfaces either flat or curved with an error not to exceed one-tenth of a wave length of light, or one four hundred thousandth of an inch.

As the established standards of length, which are the yard of Great Britain and the metre of France, are made of metal, and liable to destruction or damage, Prof. Michelson conceived the idea of determining the lengths of these standards in wave lengths of light, which would be a basis of value unalterable and indestructible. For the purpose of carrying out these experiments, the interferometer was constructed, an instrument which required the highest order of workmanship and the greatest skill of the optician. Again Mr. Brashear proved to be equal to the occasion, and made for the instrument a series of refracting plates, the surfaces of which were flat within one-twentieth of a wave length of light, with sides parallel within one second. This was the most difficult work ever attempted in the refinement of optical surfaces.

Prof. Michelson and Prof. Morley devised a method for using the interferometer to make the wave length of some definite light an actual and practical standard of length. So satisfactory was the result that Prof. Michelson was invited to continue the experiments at the Bureau of Weights and Measures, at Sèvres, France, where the standard metre, which is kept in an underground vault and inspected only at long intervals, was used for that important work. The final result of the experiments, which occupied nearly a year, shows that there are 1,553,164·5 wave lengths of red cadmium light in the French standard metre, at 15° cent. So great is the accuracy of these experiments, that they can be repeated within one part in two millions. Should the material standard of length be damaged or destroyed, the standard wave length of light will remain unaltered, as a basis from which an exact duplicate of the original standard can be made. These two marvellous instruments, the Rowland dividing engine and the Michelson interferometer, show the possibilities in the perfection of linear divisions and the standards of length.

* From the Journal of the American Society of Mechanical Engineers.

THE LJUNGSTRÖM TURBINE AND ITS APPLICATION TO MARINE PROPULSION.*

BY RONALD S. PORTHAM.

At the end of the 19th century the marine engineer's task in the selection of propelling machinery was a comparatively easy one. Practically his only alternatives were the installation of either triple or quadruple-expansion steam engines. Within the last few years, however, the range open to him has been much wider; and although the reciprocating steam engine still has many adherents, the direct-drive turbine either independently or in conjunction with a reciprocator, finds advocates for large steamers with three or four shafts. The mechanically-geared turbine either impulse or impulse reaction has rapidly come into favour for many types of vessels, and the internal-combustion engine has a school of its own, whilst recently turbo-electrical propulsion has come to the front.

It is a far cry from the first electrically-propelled 28ft. boat designed by Prof. Jacobi, which ran on the Neva in 1838 driven from a primary battery, to the 37,000 s.h.p., 32,000-ton, 22½-knot super-dreadnought, "New Mexico" (late "California"), the keel of which was laid in October, 1915. The march of progress in electrical marine propulsion, from 1838 to within the last two years, has been very slow, and the recent forward movement is remarkable and significant.

In 1903, Messrs. Nobel Bros. ran a tank vessel of 1,150 tons displacement on the Volga, the vessel's speed being about eight knots, and the total of 360 b.h.p. was supplied by three sets of Diesel engines to three motors, each driving a separate propeller. I believe three or four other similar Diesel electrically-propelled ships were built for Messrs. Nobel from 1906 to 1908, and are still in operation.

About 1912, the late Mr. Henry Mavor's firm equipped a Canadian lake steamer — the "Tynemount" — with two 250 b.h.p. Diesel alternator sets, supplying current to a 3-phase motor. This was the first example of 3-phase machinery applied to marine propulsion, but was unsuccessful owing to the difficulty experienced in running the two Diesel engines at the lower speeds.

The first practical example of turbo-electrical transmission was on the United States collier "Jupiter," of 20,000 tons displacement, and 12,000 tons deadweight, equipped with one 5,000 kw. turbo-generator of the Curtis type, driving two direct-coupled 3-phase motors, each of 2,500 b.h.p. The successful operation of this ship for more than 2½ years has resulted in orders being placed by the United States naval authorities for three electrically propelled super-dreadnoughts, of which the "New Mexico" already referred to is one.

Early in 1913, the favourable results achieved by the turbine associated with his name led Mr. Birger Ljungström, of Stockholm, in conjunction with his brother Mr. Frederick Ljungström—to seriously consider the question of electrical marine propulsion for commercial vessels. The pioneer ship built—the "Mjölner"—of 900 s.h.p., with two generating units, each of 450 s.h.p., has successfully proved Messrs. Ljungströms' contention with regard to the economical adaptation of this system, even for one of the smallest sizes of sea-going ships. This vessel has now been running since December, 1914, and the fuel consumption under the same conditions of deadweight, speed, and coal has averaged 38·6 per cent. less than that of her sister ship—"Mimer"—fitted with triple-expansion reciprocating engines.

Messrs. Ljungström recognised that an important feature in marine propulsion, and one not hitherto sufficiently recognised, was that the generating plant should be subdivided into at least two entirely independent units, so that either set could drive the ship at about three-quarters speed, running under relatively economical conditions. Naturally, this subdivision of power, though conducing to maximum reliability at sea, necessitates an efficient, light, and accessible turbine.

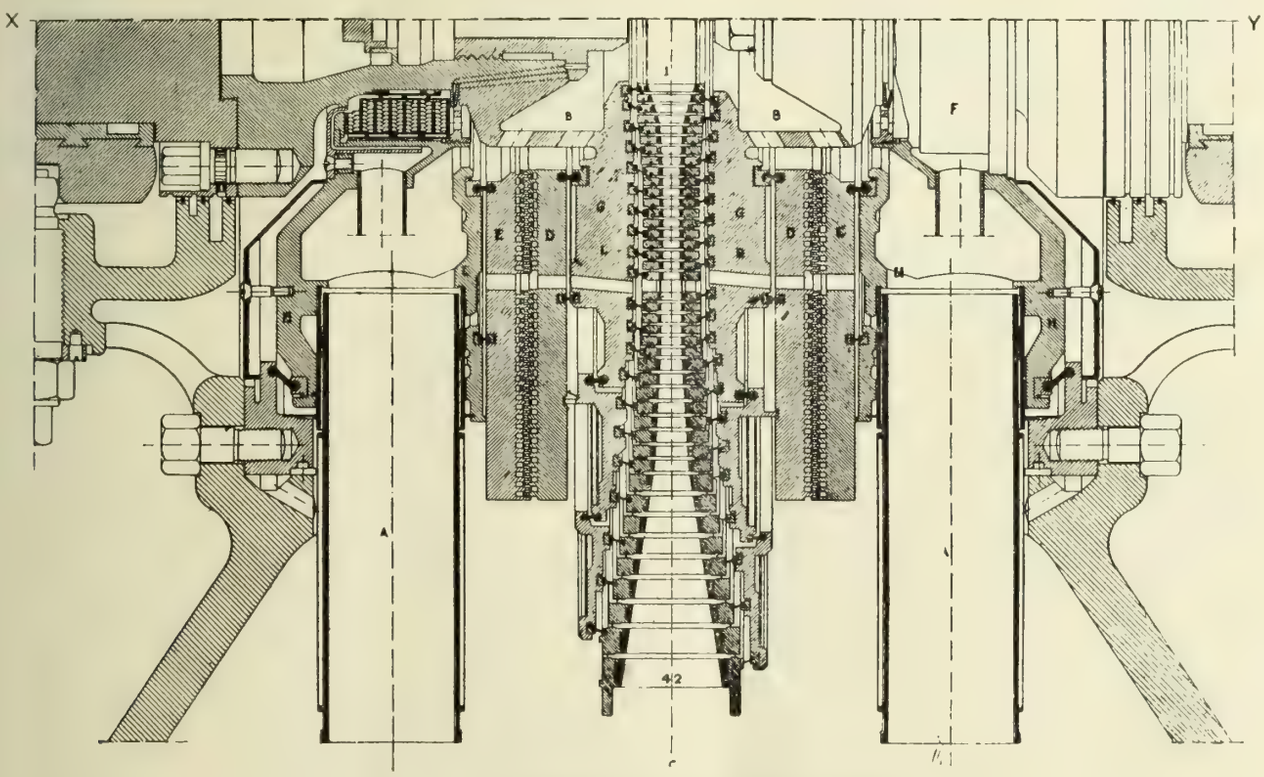


FIG. 1.—HALF LONGITUDINAL SECTION OF LJUNGSTRÖM TURBINE

In 1907, Messrs. Ljungström, in the course of investigations on the Curtis impulse and Parsons reaction types of turbines, came to the conclusion, which has been confirmed by independent investigators, that the pure reaction principle offered certain advantages over the impulse type, more especially for turbines of larger output. The drawback, however, in the reaction system was the large number of rings and blades, involving a correspondingly long rotor to ensure a reasonable efficiency, and the attendant tendency to distortion of casing with varying temperatures, necessitating considerable tip clearances and corresponding leakages.

With a view to reducing such excessive length, Messrs. Ljungström experimented on various widths of blades, and found that these could be reduced to 5 mm. in the high-pressure end up to 17 mm. in the low-pressure end without affecting the efficiency. They realised, however, that shortening the turbine axially did not solve the problem of so adjusting the passage of steam through the blading as to allow it to follow its natural curve of expansion from a stop-valve volume of about 2½ cub. ft. per pound up to a volume of over 300 cub. ft. per pound, at a vacuum of from 28in. to 28½in.

* Abstract of paper read before the Institution of Engineers and Shipbuilders in Scotland, March 21st, 1916.

They, therefore, conceived the idea of turning the plane of the blade area through an angle of 90°, thus converting the direction of steam from axial or parallel to radial flow, and were thus enabled to proportion the area of the successive blade rings so as to follow the true expansion curve of steam from turbine inlet to condenser.

Simultaneously, the great advantages were realised which would accrue were the guide blades in the ordinary turbine designed so as to revolve at the same speed as the moving

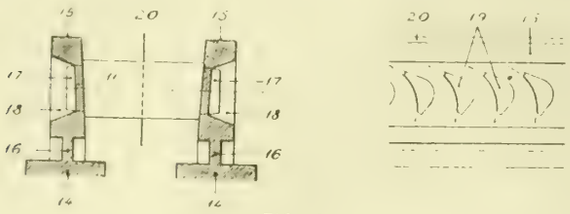


FIG. 2

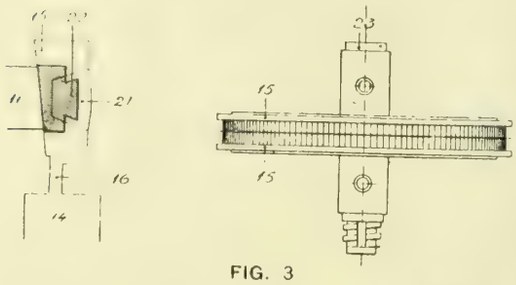


FIG. 3

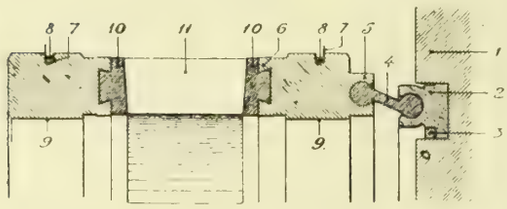


FIG. 4

blades, thus doubling the relative speed of the blade rings, and, therefore, necessitating only one-quarter the total number of rings for the same efficiency.

Earlier inventors, notably Siemens-Schuckert, had attempted revolving the fixed guide blades in the axial flow turbine by means of bevel gearings. Obviously such devices were unsatisfactory, and Messrs. Ljungström concluded that the only satisfactory method of double rotation would be on the pure reaction principle of alternate concentric blade rings. The steam reacting from the first blade ring to the next ring surrounding and concentric thereto.

As it was important that the clearance between the revolving rings should be as small as possible, the next step was to so hold them in their supporting discs that any distortion consequent on the variation in temperature between the blade ring and the framework should be eliminated. The original idea was, therefore, conceived of carrying each blade ring on its own expansion ring, and embodying a series of expansion or breathing rings throughout all parts of the turbine subject to temperature differences.

The period between 1907 and 1909 was spent by Messrs. Ljungström in preparing the designs of all the essential details, and the results of their careful work were embodied, in 1910, in the first turbine constructed by them of 750 b.h.p., running at 3,700 revs. per minute, which gave a trial steam consumption of 8·9lbs. per brake horse power per hour, total temperature of steam 626 Fah., vacuum 28·6in., and 171lbs. per square inch absolute pressure on the turbine inlet valve. Since that date an aggregate of approximately 200,000 b.h.p., of a design practically identical to their first turbine, is in operation or under construction.

Fig. 1 shows a half-longitudinal section of the turbine. The turbine revolves on an axis represented by X Y. The steam enters through the main steam pipe, branching off where it enters the turbine into two vertical pipes A A, from whence it passes by means of a number of holes B B milled in the hub of each supporting disc to the innermost turbine ring 1, then radially through the two series of blade rings to the last ring 42 on its way to the condenser. There are altogether 42 blade rings, 21 being fixed to supporting disc G R and 21 to the supporting disc G L, the discs revolving in opposite directions. It will be noted that these two supporting discs, carrying the blade rings, are each divided into three sections, connected through expansion rings, in order to avoid the stresses and alterations in shape which would arise in a solid disc subjected to the influence of varying and irregularly distributed temperatures, as would be the case when steam is first admitted into the turbine, and when variations occur in steam pressure, steam temperature, or load. Considerable temperature stresses would occur were they built in solid form, as the centre of the disc is brought into contact with high-pressure steam, while at the circumference it is in contact with low-pressure steam of correspondingly lower temperature. The supporting discs are made from chrome nickel steel.

Each disc is directly coupled to the rotor of the generator, being mounted on the overhanging end of the shaft. The centre hole is tapering, and the hub is secured to the shaft by means of a number of round keys, which are in their turn retained by a locking device screwed into the end of the shaft. The part of the shaft situated within the turbine casing, and subjected to heating by the steam, is hollow, so that the fluctuations of temperature in shaft and hub follow one another, and thus avoid play between the hub and the shaft. A general inspection of this half-longitudinal section shows a number of small dumb-bell shaped sections. These are not links, but cross-sections of circular rings made of nickel steel. They are the expansion or breathing rings which form one of the essential features of the turbine, and are interposed between any two parts which would be otherwise liable to distortion due to variation of temperature. These expansion rings are interposed between the blade rings and supporting discs, between the component parts of the discs themselves, and between the steam chests and their supporting frames.

The blade rings of the turbine form an important feature, and Figs. 2, 3, and 4 show the method of their construction. The blades themselves are made of 5 per cent. nickel steel. Calculating from the centre line X Y, Fig. 1, the first 33 rows are 5 mm. wide, the next five are 7 mm., and the last two 12 mm. and 20 mm. respectively. The blades are milled from solid rough-turned bars on ordinary horizontal milling machines and are polished to a mirror-like surface both inside and out. They are then cut into lengths 11, Fig. 2, and are notched on the ends for insertion into mild-steel retaining frames 15. A side view of such retaining frames is shown with registers or

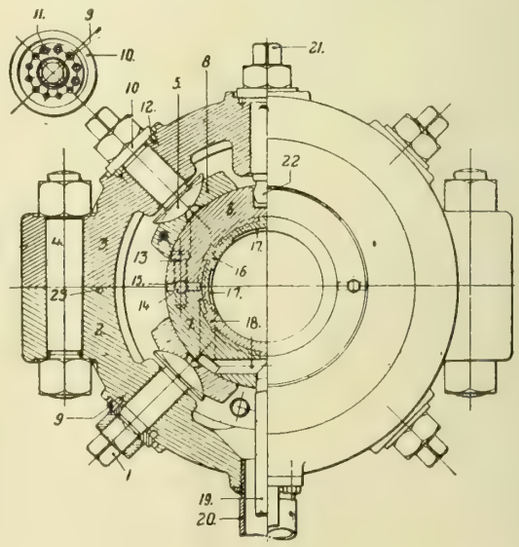


FIG. 5.

slots to receive the blades in 19. The turbine blades are retained in their positions by means of thin sheet-iron strips 20, in which are punched holes of the same cross-section as the blades, and at a distance corresponding to the pitch or spacing of the blades. These strips are applied in their places simultaneously with the assembling of the blades in the retaining frames, the angles of the blades being thus properly set, and the blades prevented from shifting during the welding operation. The discs containing the blades are mounted on a

mandrel, Fig. 3, which is held vertically. The blade ends are welded up solid in their frames by melting iron wire under the oxy-acetylene blow pipe, thus filling up the channels 18, Fig. 2. The blade ring thus obtained is then turned up in a lathe, the sheet iron strips are cut away, and the supporting mandrel removed, giving the dovetail shape 22, Fig. 3, or 10, Fig. 4. Strengthening rings 9, Fig. 4, made of the finest grade spring steel are then dovetailed into the blade ring, and the edges squeezed in so as to grip the dovetail tightly, by means of hinged rollers carried on the lathe tool rest. A groove is formed in one of the strengthening rings 9 to receive the dumb-bell-shaped expansion ring 4, the other end of the dumb-bell being rolled into the seating ring 2, which is subsequently fitted to the supporting disc, to which it is secured by a caulking strip 3. Each blade ring is now complete, with the exception of two pure nickel fins 7 which are caulked into the top surface of the strengthening rings by two pieces of soft iron wire 8. The function of the nickel fins is to prevent side leakage from any pair of counter-rotating blade rings.

Referring again to Fig. 1, it will be obvious that the steam entering the centre and flowing through the series of turbine discs to the condenser, will displace each rotating half axially outwards relatively to the other, unless this is counteracted by a corresponding reverse pressure. This is effected by a series of labyrinthic dummies E D, of which D is attached to its respective rotating disc through three expansion rings, and revolves with it; whilst E is fixed to the stationary part of the steam chest. Steam is admitted between these dummies from the centre of the turbine. The inner labyrinthic packings receive the full steam pressure, the pressure gradually decreasing from the centre until it finally drops to that of the condenser outside of the outermost labyrinth. Each rib of the fixed dummies has a small groove on its outer face, into which a folded strip of thin nickel is lightly driven.

These labyrinthic dummy packings obviously form a very accurate method of balancing the axial thrust. Should the load increase in the turbine, the revolving labyrinthic face D approaches the fixed face E, thereby increasing the space between the nickel strips, and causing high-pressure steam to enter between E and D, forcing D in the opposite direction, and automatically closing the labyrinthic openings. A small dashpot is fixed to the end of each rotor shaft for the purpose of damping any oscillatory movement which would otherwise occur. Reference may be here made to the shaft packings or glands F, Fig. 1, which reduce shaft leakage to a minimum. These packings are of nickel steel, designed to expand freely in all directions without distortion. Packing for a 1,500 b.h.p. turbine occupies a length of less than 3¼in. of the shaft, but contains no less than 158 constructing surfaces. The actual leakage through these glands is less than 1 per cent. of the maximum output of the turbine, but this is not wasted, as a separate pipe leads it to the feed-water heater, where it is economically utilised. L M, Fig. 1. shows the overload by-pass. The overload valve introduces high-pressure steam direct into the outer blade rings through a series of 60 holes drilled circumferentially in the supporting disc.

A cross-section of one of the shaft bearings of the turbine is shown in Fig. 5, and attention might be drawn to the delicate methods of adjustment possible by the construction of this bearing. It will be noted that there are four adjusting screws fitted with hemispherical heads. Each adjusting screw 1 is provided with a pair of locking washers 10 on which are 12 and 11 holes respectively, thus giving 132 different positions for each turn of the adjusting screw, corresponding to a thread with a very fine pitch. It will also be noted that there is an eccentric ball 22, which admits of axial adjustment by turning its corresponding screw.

All bearings are automatically lubricated by oil under forced pressure, and a feature of the lubricating system of the Ljungström turbine, which is common to each installation, is that it is impossible to start the turbine unless the bearings are lubricated at their normal oil pressure, as should for any reason the oil supply fail, the turbine will automatically shut down. A cylindrical chamber, by the side of the turbine, contains the throttle valve, details of which are shown in the cross-section, Fig. 6.

The oil pump is of the ordinary geared type, driven directly by the governor spindle, maintaining a pressure of 35lbs. per square inch, lowered to about 15lbs. per square inch for the bearing lubrication by means of a reducing valve. The throttle valve is normally pressed to its seat by means of a powerful spiral spring acting vertically downward. On the lower side of the valve spindle is attached a double-beat piston. The oil pressure acts on the bottom side of this piston, and consequently has to work against the spiral spring in order to open the throttle valve. Thus any variations in oil pressure varies the position of the throttle valve, which, through a floating lever and side shaft, maintains a constant relationship between the position of the stop valve and that of the governor, Fig. 7, which latter is of the Chorlton Medlock type.

An emergency release device is supplied by a steel cable under tension which, so long as it is in tension, holds shut an oil relief valve in the relay controlling the stop valve; in the event of the turbine attaining an excessive speed or the bearings becoming unduly heated, the cable slackens, thus releasing a lever at the side of the stop valve; this releases the oil pressure, the tension spring operates, and the turbine stops.

To start the turbine, the handle shown at the top is unscrewed a couple of turns, so as to admit sufficient steam

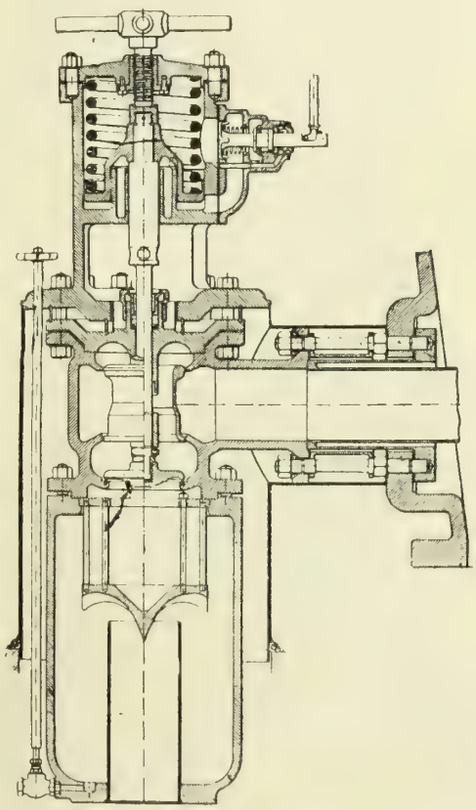


FIG. 6.

to raise the disc valve from its seat, and allowing a sufficient amount of steam to leak past the double-beat piston valve, which is quite sufficient to warm up the turbine in a few minutes. A few strokes of the hand pump raises the oil pressure sufficiently to lift the piston on the valve spindle against the downward pressure of its spring, so that the turbine starts, and when once it has attained its maximum speed the regulation thereafter becomes automatic.

The generators are of very substantial construction, the whole machine forming a rigid cylindrical structure, which is adequately supported on the condenser inlet, thus forming a direct path without the necessity of intermediate joints. As the turbine casing is itself part of the condenser chamber, it requires no external lagging.

The relative lightness of the rotating parts of the Ljungström turbine, coupled with their mechanical construction, should dispel any criticism respecting the overhang. In the case of a 1,500 b.h.p. machine, the weight of each revolving part, that is, turbine rings, supporting disc, and attached labyrinthic packing, are only 265lbs. and 303lbs. respectively, while the maximum overhang to the outside of the bearing is 10½in. The total weight of turbine and steam chests is about 1,000lbs. The complete turbine can be removed for inspection, and opened up in two hours. The over-all diameter is 29in. and over-all length across the steam chests 27½in.

No insulating jackets need be removed to make bolts and nuts accessible. The internal parts of the turbine are made accessible by lifting off the upper part of the turbine casing. The couplings between the generator shafts and the turbine wheels are then unscrewed, and a clamp is applied to the steam chests. By the aid of this clamp the whole turbine and its steam chests are lifted together.

The whole turbine has been so designed as to be manufactured in ordinary lathes, such as may be found in any modern engineering shop. The fitter is almost entirely replaced by the turner. The manufacture of the blade rings is ordinary repetition work, to which unskilled boy or girl labour can be trained in a few weeks. The completed machine has a factor of safety larger than in any other type

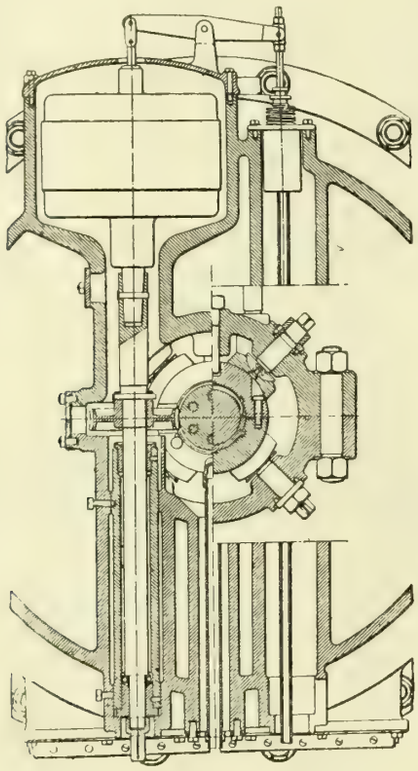


FIG. 7.

of turbine. Blade stripping is unknown, due to the mechanical construction of the rings, the blades being firmly held at both ends.

Some Steam Trials of Ljungström Turbo-Alternators.

Date of Test.	Normal maximum Output in kw.	Trial Output in kw.	Steam per kw.-hour. Lbs.	Steam per b.h.p.-hour. Lbs.	Pressure on Turbine Inlet (absolute). Lbs. per sq. in.	Superheat. Degrees Fah.	Vacuum. Per cent.	Thermo-dynamic Efficiency compared with ideal engine. Per cent.
Dec., 1911....	1,000	1,000·5	11·6	8·3	168	302	96	76
July, 1914....	1,000	990	12·7	9·0	160	150	94	77
Oct., 1915....	6,000	2,000	11·1	7·9	170	270	97	79
Jan., 1916....	3,000	2,700	11·15	8·0	160	280	88	87

Attention is called to the remarkably good results shown by the 3,000 kw. turbine at 90 per cent. full load. Reduced to marine conditions of 220lbs. boiler-gauge pressure per square inch, vacuum 95 per cent., and 240° Fah. superheat on the inlet valve, the steam consumption of the turbine would be 7·25lbs. per brake horse-power, or 8lbs. per shaft horse-power per hour, including generator and motor losses, but excluding condensing and propelling auxiliaries. With electrically-driven auxiliaries, and including excess steam tapped from the turbine at 30lbs. pressure for feed heating purposes, this would represent a total propelling steam consumption of 9lbs. per shaft horse-power per hour, equivalent with coal of 14,000 B.T.U's. and an actual evaporation of 10lbs. of steam per pound of coal with 210° Fah. feed temperature to $\frac{9}{10}$lb. of coal per shaft horse-power.

It might be said that trial conditions of consumptions may not be maintained in practice, due to possible wear of the labyrinthic edges which vary from ·004in. to ·01in. in the different radii of the blade rings. It has been found, however, that there is no perceptible increase in consumption. Recent trials carried out with the 1,000 kw. set installed in 1913, at the North Metropolitan Power Station, Willesden, show no increase in the original consumptions after a period of two years' continuous operation for 18 hours a day.

It is not unnatural that the principle of electrical marine propulsion should be criticised on the ground of converting mechanical energy into electrical energy at a loss of about 5 per cent., then reconverting such electrical energy into mechanical energy at an additional loss of 5 per cent. It will, however, be agreed that it is the net result which has to be considered. As reversing is effected on the motors, an astern turbine is dispensed with. The prime mover runs under the best possible thermal conditions, which include as high a superheat as can be commercially obtained without unduly sacrificing the efficiency of the boilers. The gain in thermal efficiency due to such increased temperature eliminates the electrical conversion losses. Further, the Ljungström electrical method of propulsion, in conjunction with mechanically-geared motors, is a system which embodies the maximum degree of reduction between prime mover and propeller shaft, whilst the total weight of engine-room machinery is lower in the smaller powers and not greater, even in the larger-powered merchant ships, than any form of mechanical reduction with the ordinary impulse or impulse-reaction turbine. The reduction in weight of boiler-room machinery is obviously in direct proportion to the steam consumption of the propelling plant.

Reference is made to merchant ships in this category as in the case of torpedo-boat destroyers, or express Channel steamers, where the propeller speed is relatively high and the total shaft horse-power relatively large in comparison with the displacement of the vessel, mechanical or hydraulic reduction in some form or other still offers advantages over any system of electrical propulsion. As the field, however, which can be profitably covered by electrical propulsion ranges from merchant ships as small as the "Mjölner" to as large as the "Mauretania," it is obvious that there is a sufficient scope for the system under review.

Further, in the case of battle-ships or battle-cruisers of sufficiently large power, turbo-electric propulsion has many advantages, given a prime mover of the efficiency of the Ljungström turbine. The generating plant can be effectively subdivided into four units, which ensures military efficiency. Economy in cruising is obtained by varying the number of poles on the propelling motors, the current being supplied from one of the generating sets.

It is desirable to have at least two independent turbo-generators of equal power for each marine installation. Not only is this advisable in respect to the factor of safety through such duplications, but also in regard to the economy to be derived therefrom when running at reduced speeds. There is no necessity, however, in any class of merchant ship to increase the weight and expense of the motors by pole-changing devices. To run at half-speed or about one-ninth power one of the two generator sets would run at half-speed, absorbing about 25 per cent. of its normal full power. Between three-quarters and full speed, both sets are run in parallel at speeds corresponding to these two requirements, consequently the turbines run under at least as efficient conditions, and with the same elasticity, as in the case of ordinary geared turbines where the regulation is effected on the throttle or nozzles of the turbine. The reversing switch and its resistances need only be used when manœuvring astern, the whole of the regulation from dead slow to full speed and vice versâ can be effected on the turbine. The motor speed falls in direct proportion to the reduction of speed on the prime mover.

It may be of interest to know that 21 ships of an aggregate shaft horse-power of 32,000 are at present under construction on the Ljungström turbo-electrical system for British, Russian, Japanese, Swedish, Norwegian, and Danish owners. These vary from ocean-going vessels of 5,400 s.h.p. to river steamers of 550 s.h.p. They include one light-draught paddle steamer of 1,500 s.h.p., the power being transmitted from the turbo-alternator to two electric motors running at 450 revs. per minute. Each gearing by single reduction to the corresponding paddle-wheel shaft runs at from 35 to 40 revs. per minute.

THE COMPOSITION AND USES OF TIN.*

BY L. ADDICKS AND W. A. COWAN.

A SPECIFICATION to be generally adopted must reasonably reconcile the inherently different points of view of producer and consumer. This requires a classification of the material which will allow the producer to market everything produced and the consumer to choose the grade suitable for his particular work, paying accordingly. It is obviously necessary to understand the situation from both sides when a specification is to be drawn up, and this providing of a common ground is one of the chief functions of this society. In the case of tin this mutual understanding is wholly lacking at the present time, due chiefly to the great geographical distance between the points of production and consumption and the speculative basis on which tin is handled by a broker as a middleman.

Practically speaking, there is but one ore of tin, cassiterite, which in some cases is almost pure stannic oxide. It occurs as vein tin in mineral lodes and as stream tin in alluvial deposits. Vein tin generally is associated with other minerals, while stream tin is much purer. Tin is found in paying quantities in very few places. The relative importance of the sources may be judged by their approximate outputs, stated herewith in long tons of metallic tin per annum:—

	Long Tons.
Straits	60,000
Bolivia	20,000
Banka and Billiton	17,000
Cornwall	5,000
Australia	4,000
China	4,000
South Africa	2,500
Miscellaneous	2,500
	115,000

The Straits tin comes from Penang, Singapore, and Malacca, the two latter being towns on the Malay peninsula and the former an island off the West Coast. Banka and Billiton are islands in the Dutch East Indies. The metallurgy of tin is very simple in the case of the pure deposits. The ores, which run but a few tenths of a per cent. in tin, are readily concentrated by ordinary wet methods to a 60 to 70 per cent. product, on account of the high specific gravity of cassiterite. The concentrate is smelted in a reverberatory furnace with coal as a reducing agent and the fluxes necessary to slag the remaining gangue. The resulting crude tin is then refined by liquating and drossing. As stannic oxide is difficult to reduce, the various impurities present are also reduced and largely collected in the crude tin from which they can be but imperfectly removed by liquation. The result is that the purity of the final product depends largely upon that of the original tin stone, certain deposits have come to have a reputation as producers of high-grade tin. At this writing electrolytically refined tin is just beginning to appear on the market in quantity from the treatment of foul bullion produced in the usual way from Bolivian concentrates. Electrolysis, of course, should obliterate the past history of the crude tin.

It has been the fixed policy of the Dutch and English colonies to smelt the tin concentrates at the point of production, export duties having been imposed on tin ores. Prior to the war, the Bolivian concentrates were sent to England and Germany, where they were worked into a low-grade tin. They are now coming chiefly to the United States, and the crude tin obtained therefrom electrolytically refined as stated. Up to this time it has been impossible to buy the desirable Straits and Banka products which make up the bulk of the high-grade output except upon reputation by brands, and the sales in America have been handled by brokers who are practically subject to the dictation of the Dutch-English ring controlling those brands, in spite of the fact that America consumes 45,000 tons a year, or over a third of the world's production. The recent importation of Bolivian concentrates and their local treatment, it is to be hoped, will alter this situation.

* Presented at the annual meeting of the American Society for Testing Materials, June, 1916.

According to the rules of the London Metal Exchange, tin is merchantable as standard tin only when the warrant is accompanied by analysis certifying that the metal contains either 99 or 99·75 per cent. of pure tin, according to whether the quality is that of common tin or refined tin, and also that it is of the correct physical condition.

Straits, Australian, English Refined, Banka and Billiton fall within the highest class, namely, refined tin. The Chinese tins are off-grade, carrying considerable lead, and the German tins resulting from the smelting of Bolivian concentrates are very foul. Off-grade tins are sold on the basis of a sliding scale for tin contents. The worst of them will run over 90 per cent. tin, while the high-grade tins will run 99·8 to 99·9 per cent. The only tests required for good merchantable tin aside from its origin are that it shall run at least 99·75 per cent. tin and that a bar when nicked and bent double shall not crack.

The consumer has generally met the situation in which he finds himself by buying a first-class brand, analysing it when he gets it, and then sorting the lots by analysis for certain uses. It is of doubtful value to give here a long list of analyses of different brands, but a rough idea of the various grades given in Table I. will illustrate the situation.

TABLE I.—*Analyses of Different Brands of Tin.*

All Values in Per Cent.

Elements.	Electrolytic.*	Straits, Banka, Billiton.	Australian	English Common.	English Refined.	German.	Chinese.	Bolivian.
Tin	99·80–99·95	99·80–99·95	99·75 99·90	99·20	99·90	99+	95–99	93·0
Antimony	—	0·02	0·04	0·25	0·04	0·65	0·02 0·40	4·0
Arsenic	—	0·04	0·06	0·05	0·05	—	0·06	0·2
Bismuth	—	none	0·003	0·06	0·001	—	0·01	0·1
Copper	—	0·01	0·04	0·08	0·015	—	0·09	0·5
Iron	—	0·03	0·03	0·004	0·002	—	0·15	0·02
Lead	—	0·02	0·04	0·36	0·01	0·14	0·3–4·0	2·7
Zinc	—	0·03	none	0·006	0·01	—	none	0·03

* Representative analyses of the new electrolytic tin are not available at this writing.

The principal uses of tin, aside from tin salts and pigments, are as metal in pipe, fusible boiler plugs, &c.; as a coating, as in tin plate, tinned wire, tin-lead foil, &c.; and in an alloy, as in bronze, babbitt, solder, britannia metal, type metal, fusible alloys, &c. The bronzes are alloys with copper and zinc; babbitt metal with antimony and copper; solder with lead and a little antimony; britannia metal with antimony; fusible alloys with lead, bismuth, and cadmium.

The impurities in tin may cause trouble by poisoning, as in the case of pipe and tin cans; by impairing fluidity, causing an excessive consumption of tin used for coating, or making solder hard to apply; by fouling an alloy and spoiling its appearance; by impairing the ductility of alloys which have to be worked, such as bronze or britannia metal; by causing local galvanic action and possibly tin pest, and by affecting the melting point of fusible alloys.

In a general way the purest obtainable tin is desired for pipe and boiler plugs. The United States Bureau of Standards has found that zinc, generally introduced by a foul pot when remelting tin, causes serious deterioration in boiler plugs and recommends, as nearly as possible, absolute freedom from zinc and lead.

One of the tinplate manufacturers states that lead makes a mottled finish, iron causes rough surface and impairs fluidity, and arsenic and zinc tend to form poisonous salts. They suggest maximum allowable percentages as follows:—

	Per cent.
Lead	0·04
Copper	0·02
Iron	0·05
Arsenic	0·05
Antimony	0·02
Zinc	0·05

One of the manufacturers of wrought bronze gives the following maximum allowable percentages:—

	Per cent.
Antimony	0·01
Bismuth	0·001
Lead	0·05
Iron	0·05

MALLEABLE AND CAST STEEL.*

BY ANDREW HARLEY.

BROADLY speaking, the subject in which we are interested is the production of light castings in malleable iron and mild steel. My experience in recent years has been in the production of castings for the motor and cycle trade, and what I have to say naturally applies more particularly to this class of work. Such as it is, the field is a vast one, and it is obviously impossible in the time at my disposal to cover the ground even in the most general manner. I therefore propose to mention a few general considerations, to deal with the production of molten metal, and to discuss a series of tests which I have made on cast malleable and cast steel. Among foundrymen sharp differences of opinion exist concerning the best methods of production, and among both foundrymen and engineers there is considerable diversity of opinion as to the relative merits of the two metals as applied to various purposes. With regard to the former, these differences of opinion occur at every stage of production. One man puts his faith in certain brands of iron, while another may not worry about the particular brand if the analysis is according to his liking. One man will say that good malleable cannot be made with cupola metal, another will affirm that he is doing it. On the moulding floor one man favours the use of chills, another places a feeder wherever he thinks it necessary, and sometimes where it is not. In regard to annealing malleable, no two men think alike. One man will swear by round ovens, another will swear at them. One man believes in soaking, another will ask how it is possible under the present restrictions.

The cost, or rather selling price, has a good deal to do with the question of quality. The cult of cheapness can be carried too far. The malleable trade particularly has suffered from this. The cutting of prices has not always been accompanied by a reduction in cost due to improved methods of production. More often the reduction in cost has been accomplished by the use of inferior material. The buyer is not free from blame, however. With too many, orders are placed at the lowest price, irrespective of quality. They have acted on the principle that "malleable iron is malleable iron all the world over." People sometimes get what they pay for.

We must constantly strive to cheapen production, but we must also strive to improve the quality of the product. The processes involved must be carefully studied, and this can only be done by the use of scientific equipment, handled by men with some scientific training. Much unnecessary waste would be avoided, provided the management is competent to apply the scientific information in a practical manner.

There is another factor influencing foundry costs, and that is the influence of design. In fact, the design not only influences cost, but very often the quality of the casting. The foundryman should be consulted in this matter, and in an efficiently managed concern this is done, and any alterations suggested are made where possible. Even when the best has been done with a design, in most cases there will still be plenty to engage the foundryman's skill.

With regard to the relative cost of malleable and steel castings it is difficult to give a definite answer. For very light work, say under ⅜in. section, it tells against steel; over this section it favours steel. This is necessarily a rough generalisation, as obviously much depends on the size and shape of the casting. The actual foundry cost is not the only point to take into consideration. At present greater machining allowances are required for steel. On the other hand, the greater strength of steel allows a relatively lighter casting to be used.

For certain classes of work, such as cycle parts, a fine skin is absolutely essential, as the majority of such parts have not only a very small machining allowance, but subsequently have to be enamelled or plated, whereby any irregularity on the surface would be intensified. Malleable, therefore, is in favour for such work, but progress is being made with steel in this respect.

Broadly speaking, the particular melting method adopted is governed by the class of work and the output to be handled. Certain prime essentials are necessary in every furnace melting any metal on a commercial scale. All foundrymen are acutely aware of what these essentials are. The metal must be of ample fluidity, correct and regular composition, and produced at a reasonable cost.

Dealing with malleable first, the three principal types of furnaces in use are the crucible, reverberatory or air furnace, and the cupola. The air furnace is used chiefly in the production of black heart malleable, with which we are not much concerned. In the production of Reaumur malleable, the cupola and crucible furnace are almost universally used. Where the output justifies it, the cupola should have preference. The crucible furnace usually is credited with giving better quality metal than the cupola. This may be so, although it is not altogether obvious why it should be so.

It may be due to the fact that the percentages of carbon and silicon are not subject to so much alteration in the process of melting. On the other hand, it has always seemed to me that variations in the iron, as delivered, were more likely to be perpetuated in the molten state when melted in the crucible furnace. The cupola can be operated more economically, the metal can be obtained in a higher state of fluidity, and I am convinced that by taking certain precautions, metal can be obtained which is much more regular in composition.

In the production of malleable, a uniform composition in the hard state is of the utmost importance. Irregularities in the hard metal lead to most of the difficulties in annealing. I do not advocate any particular analysis as being right and all the others wrong. What I want to emphasize is, that, having decided on what is the most suitable composition for your class

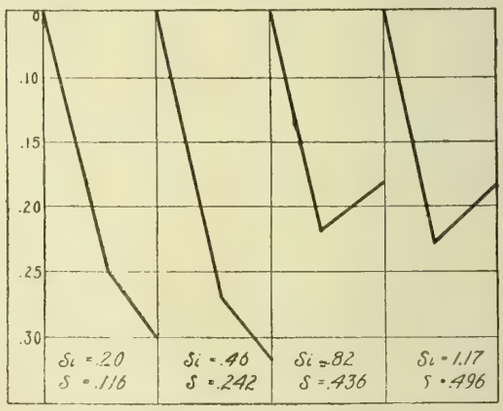


FIG. 1. CHART SHOWING SHRINKAGE OF MALLEABLE IRON.

of work, the furnace should give (within reasonable limits) molten metal of that composition throughout the melt. Any change in the metal must be intentional and known so that the castings subsequently can be graded and given the annealing treatment most suitable to their composition.

In the following I will describe as briefly as possible the means which I have found it necessary to adopt to obtain this control. For the sake of brevity I must make certain assumptions. I must assume the existence of a laboratory or facilities for obtaining analyses. I also assume that the furnace is fairly correct in its proportions and that there is uniform supply of air at the correct pressure. In other words I am confining myself altogether to the raw material which goes into the furnace. The pig iron must be bought to specification and should be adequately checked. We have found it advantageous to give each separate consignment a reference number. This number is not only attached to the heap of pig iron in the yard, but is used in all subsequent records. A separate stock card is filled out for each consignment. This card shows the analysis and also the usage.

Scrap must be graded according to analysis, the silicon content being sufficient, as a rule. The grading of scrap is rather important, although it might be inferred that if the molten iron is regular in composition, the scrap will be so also. If the scrap is melted daily, however, the composition of the metal will change, due to the fact that a certain portion of the metal is, of necessity, melted over and over again. If one could be sure that the whole of the previous day's "git and runner" metal was obliging enough to make its way into the next day's castings, then everything would be all right. As it is, to keep perfectly straight, small daily adjustments would be necessary in the pig used. To avoid this, the scrap from one mix is accumulated so long as that particular mix is in

* Abstract of an address delivered before the Birmingham branch of the British Foundrymen's Association.

use. If the silicon has been kept fairly regular, this heap of scrap can be incorporated in the mix at a subsequent date, with the comfortable feeling that you know what you are using. If the silicon content has altered radically through some unforeseen cause, this is quickly known by the daily analysis of the cast metal, and both castings and scrap, with this altered silicon, are separated from the normal metal.

Coke of the best quality must be used. The sulphur particularly should be as low as possible. Ordinary malleable pig irons usually contain a pretty high percentage of this element, and it is undesirable to increase this by any appreciable amount. The coke also should be uniform physically. The coke we are using at present shows the following average composition: Fixed carbon, 93·65 per cent.; ash, 5·65 per cent.; and sulphur, 0·70 per cent.

Definite knowledge must be acquired with regard to the inevitable changes that take place in the composition of the metal during the melting process. These changes must be allowed for. The elements affected are carbon, silicon, and sulphur. The amounts of these elements present and also the relative proportions, largely determine the annealing treatment required. We have found that these losses and gains vary throughout a heat. With silicon, for instance, the loss in our practice at the beginning would be 0·23 per cent. This would diminish fairly regularly until 0·14 per cent. only was recorded. Then, just at the end, we got a sudden jump back to 0·21 per cent. Sulphur acts in much the same way. At the beginning we had an increase of 0·07 per cent., but toward the end this was reduced to 0·003 per cent.

The importance of good, hot metal of suitable and regular composition cannot be over-emphasized. This applies to all metals, but particularly to malleable iron and cast steel, and expenditure to secure this is amply justified. It is the foundation on which a good casting is made possible. Neglect or carelessness in this direction renders all subsequent care and skill useless. Many of the troubles that are usually assigned to the defects in moulding and coremaking really originate in defective melting. In casting malleable, for instance, sears, cracks, draws, and blow-holes may be avoided to a considerable extent, but over and above all this, the successful annealing of malleable is only rendered possible by the metal being of suitable and regular composition.

The annealing of malleable requires a good deal of skill and experience, even when the hard metal is everything that it should be. There is no royal road to success in this process. Each man must work out his own salvation. The knowledge we acquire from others no doubt is useful, but the knowledge obtained from hard experience is the best. The following observations on annealing are not advanced, therefore, as infallible dicta. They are, however, the result of practical experience and may be helpful to some who are engaged in this most difficult business. If I tried to sum up my views in one sentence on the metallurgical process of annealing, the sentence would run somewhat as follows: "Any process in which equilibrium is established and maintained between the breakdown of the cementite and the diffusion of the carbon towards the exterior is likely to give satisfactory results."

The precipitation of carbon is governed more by composition than anything else. Take the influence of silicon, for example. With low silicon metal of say 0·3 per cent., precipitation is retarded. With a high silicon metal, on the other hand, precipitation may take place too soon, or in other words, at too low a temperature. Very little carbon would be removed and a kind of black heart would be produced.

As Hatfield has pointed out, there are two phases of this annealing process: first, elimination of carbon; second, softening of the interior by precipitation of the annealing carbon. Each phase must be accomplished at the proper time by establishing equilibrium. The treatment necessary to obtain this equilibrium will vary with the composition. The most favourable period for the removal of carbon is the one just preceding actual precipitation. Where the composition of the iron is such that precipitation may take place at a low temperature, equilibrium must be established between the removal of the carbon and the return of the annealing carbon into solution.

The influence of silicon and sulphur should be considered together inasmuch as silicon favours precipitation of carbon and sulphur retards it. It follows that the primary effect of either is modified by the relative amounts present. In fact, the influence of these constituents must be so regulated as to obtain the balance already mentioned between the rate of diffusion and the breakdown of the cementite. To illustrate this point, a low silicon metal of say 0·3 per cent. which is quite annealable with 0·25 per cent. of sulphur, is almost unannealable with 0·5 per cent. of sulphur. On the other hand, a higher silicon of say 0·75 per cent. will give very indifferent results with low sulphur, the best results being obtained when associated with 0·45 per cent. These statements may not hold good where manganese is present to any extent.

In most Reaumur metal the percentage of manganese is very low, as it ought to be. In black heart you will often find from 0·4 to 0·5 per cent. present. In the absence of sulphur this no doubt serves a useful purpose in retarding precipitation to some extent and enabling some carbon to be removed.

Many questions are always asked regarding the practical details in annealing. Sometimes these questions are not answered. I would say this, however, that all such practical details centre in the problem I have been dealing with. The design of the oven naturally should give as even a distribution of heat as possible. There is no oven built in which the heat is quite evenly distributed, and I have often been thankful for this. With large ovens, there is generally a considerable variety of work, with varying sections. By exercising discretion in arranging the castings in the oven, a variety of work can be satisfactorily dealt with. Variations in the ore strength also are made to overcome this difficulty. Where there is a battery of smaller sized ovens, the castings

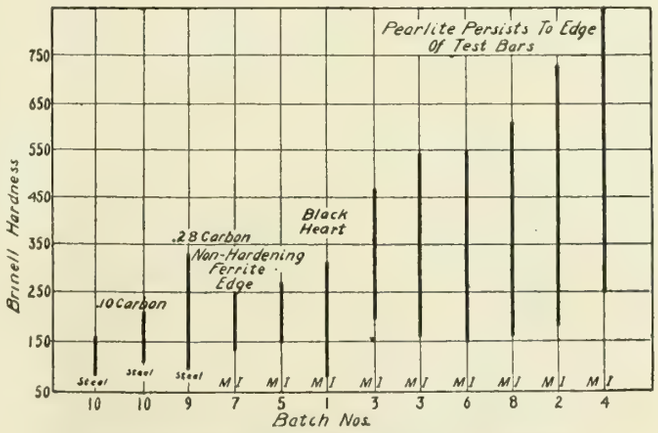


FIG. 2. INCREASE IN HARDNESS PRODUCED BY QUENCHING SPECIMENS FROM 820°C.

can be more closely graded according to weight. A further advantage is that with such a battery, extensive delays are avoided. Ovens are at all stages of firing and unloading and an even flow in deliveries is secured. There are many advantages about such an arrangement, but one disadvantage is the somewhat higher cost of annealing.

If removal of carbon is too rapid, owing to excessive temperature and too strong ore, then the complaint known as peeling occurs. If the temperature is too low, or the ore too weak, then hardness results. With a medium silicon iron in a coal-fired oven, the time necessary for diffusion is usually obtained by damping down for the night or soaking as it is called, but similar treatment in a large gas-fired oven of say 10 tons capacity might not be satisfactory owing to the longer time such an oven holds its heat. In fact, removal of carbon may be taking place all through the night. In such a case the shutting down of the oven for 24 hours or so in the middle of the fire would prove advantageous. If a high silicon iron is used, the operation may be affected with a total fire after coming up to a heat of 3½ days, even for the thickest section. In this period 1½ days would be spent in soaking or diffusing. The carbon removed is, of course, not very large, but for many purposes the malleable is quite satisfactory. If a better quality of iron is desired, the addition of two days to the firing time will produce the extra elimination of carbon which is necessary to give the superior quality to the material.

With reference to soaking, theoretically a continuous fire is no doubt quite possible, but practically we consider soaking advantageous. If the elimination of carbon is proceeding

too vigorously, it allows equilibrium to be established. The size and shape of the pans, strength of ore used, the temperature and time taken, all have to be adjusted to the one end, but it must be borne in mind that many such details are constantly changed, and necessarily so, according to the size, shape, and composition of the castings.

If it is of any interest, I may mention that we use gas-fired round ovens. We make our own pans, and a useful thing to remember here is that a pan should be made of metal which resists annealing. In regard to ore, we use all strengths ranging from all black to 3 to 1. The analysis of good annealing ore should be approximately as follows: Ferric oxide 84 to 90 per cent. and silica 8 to 13 per cent. Lime should be absent. Ferrous oxide should not be present, and anything more than 1 per cent. should be objected to.

In the production of molten steel of low carbon content, we are up against a much stiffer proposition than in the melting of either malleable iron or cast iron. It is only in comparatively recent years that anything like success has been achieved. In making this statement I am referring to mild steel capable of being run into light castings, many of them intricate in design. Furthermore, the moulds are only skin-dried, as a rule.

It is interesting to compare the melting temperatures of grey and malleable iron and steel. Ordinary grey cast iron melts at about 1,150° C.; malleable iron at approximately 1,250° C.; and mild steel, about 1,570° C. The pouring temperature, of course, is a different matter entirely. In the process I am about to describe where a bulk of about 1,200lbs. of molten steel has to be cast in one heat and into a large number of small moulds, the temperature of the metal has to be very much higher. In fact this must be in the neighbourhood of 1,900° C. In other words, we require a margin which must be higher by at least 300° C.

The general types of steel furnaces in use are the crucible, converter, open-hearth, and electric. Each of these four divisions represents wide systems in which there are many varieties. The process of melting which I am about to describe involves the use of a converter of the stock type. The Bessemer converter, of course, is the father of all such types. The chief modifications are that the pig iron, instead of being melted in a cupola is melted in the converter. Also, instead of being blown from the bottom as in the Bessemer converter, the metal is surface-blown. The surface-blown method also is used in the Tropenas furnace, but in this case the pig iron is melted in a cupola, as in the Bessemer process.

Small-capacity converters have been tried many times, but with varying success, the great difficulty being to obtain a metal of sufficient fluidity to cast the general run of light work in an automobile foundry. A larger-capacity vessel would no doubt give somewhat hotter metal at the moment of pouring, but a proportionately larger number of moulds would have to be poured, and before the finish a larger proportion of the metal could not be cast satisfactorily. Where castings of a considerable variety in weight are handled, this trouble would be obviated to some extent by grading the work on the floor.

The melting of the charge in the vessel by means of an oil burner is an important factor in obtaining very hot steel. Before this operation is completed the lining has attained a very high temperature, thus conserving the heat created during the blow proper. Furthermore, the escaping heat during the melt is used to heat a regenerative chamber. The air is passed through this chamber when blowing and enters the vessel at a temperature of 300° C.

What I have said about care in the selection of raw material for malleable melting applies equally to steel. In fact, more so, because I doubt very much whether it is possible to perform this job properly without knowing the exact composition of the pig iron and also making a carbon test for each melt. That is the minimum.

A typical analysis of pig iron to be used for conversion follows: Total carbon, 3·88 per cent.; combined carbon, 0·20 per cent.; graphitic carbon, 3·68 per cent.; silicon, 2·53 per cent.; sulphur, 0·04 per cent.; phosphorus, 0·04 per cent.; and manganese, 1·10 per cent. Consistently good results have been obtained from pig iron of this composition, the steel pouring hot to the finish. Slight variations in the silicon and manganese content are allowable. Furthermore, silicon should not drop below 2·3 per cent., or manganese 0·8 per cent. if the molten steel is required to run very thin castings. The charge takes about two hours to melt and about 20 minutes to blow. The blast pressure for melting is about 1¼lbs., and the pressure for blowing about 2½lbs. at first, afterwards increasing to 3lbs.

Assuming that the blow is finished, the composition of the metal should be approximately as follows: Carbon, 0·1 per cent.; silicon, trace; manganese, nil; and sulphur and phosphorus, 0·04 per cent. The metal now has to be carburised and deoxidised. This is done by the addition of the mix. The composition after the additions should be approximately: Carbon, 0·23 per cent.; silicon, 0·2 to 0·3 per cent.; manganese, 0·4 to 0·5 per cent.; sulphur and phosphorus, 0·04 per cent. The mix is made up from spiegel, silicon-spiegel, and pig iron, the quantity of each needed being calculated to bring the composition up to the second analysis given.

Taking it all around, the difficulties in the way of producing mild-steel castings are great, but much progress has been made in recent years. The manufacture of malleable is a much older business, but the progress made is not what it should be. Malleable iron has possibilities, but the trade suffers from a spirit of conservatism and secrecy. Looking through the various batches of malleable received, I have come to the conclusion that there is a tendency among modern malleable founders to use a higher silicon iron than was used in the earlier days. This may be due to the difficulty of obtaining irons with low sulphur. I do not think, however, that the ideal annealing process required by the new conditions has been obtained. The rapid decomposition of cementite into pearlite and graphite is not enough to make a good malleable casting, and an effort should be made to understand more fully the annealing treatment required for metals of varied composition. With regard to steel, it cannot be denied that we have here a material much superior physically. Notwithstanding its terrible propensity for blow-holes, &c., and the many problems that confront the founder of mild-steel castings, I am convinced that great developments will take place in this industry in the immediate future. In this development, the electric furnace will play an important part.

In the accompanying illustrations, Fig. 1 is a graphic representation of the shrinkage of malleable iron. Most malleable founders have experienced difficulties from cracking and other causes as a result of variable shrinkage. It will be noted that, while the shrinkage in the white casting only varies slightly in low and high silicon, the annealing produces a further shrinkage in the low silicon and an expansion in the high silicon iron. The two lines at the left, Fig. 1, indicate the shrinkage in the white casting, while the other two lines represent the shrinkage of the annealed casting. This phenomenon is of the utmost importance, both to pattern-makers and moulders, and further indicates the necessity of a thorough knowledge of irons in use. Time only permitted the four tests indicated in Fig. 1, as otherwise a few tests would have been made between silicon limits of 0·50 per cent. and 0·70 per cent., which would have determined the neutral zone where no further shrinkage or expansion takes place with annealing.

Fig. 2 is a graphic representation of the increase in hardness, measured by the Brinell machine, of steel and malleable iron as annealed, and the same material quenched in water from 820° C. It will be noted that in the first set all the samples are machinable, and that while they vary considerably, that variation is much smaller than shown in the quenched state. The steels vary according to the carbon content, but no heat treatment would render a 0·15 per cent. steel unmachinable. The malleable specimens, however, with a few exceptions, are quite unmachinable after this treatment. Since certain brazing and other operations approximate this treatment, it is of value to know which type of malleable is unsuitable for receiving any subsequent heat treatment.

Referring to Fig. 2, it may be stated definitely that any cast malleable of high silicon content in which a large amount of carbon is left in the graphitic and combined form is unsuitable. Even a black heart malleable containing no combined carbon is hardened considerably after quenching. The most suitable iron for this purpose is a low silicon, fairly high sulphur metal, in which the annealing is accomplished by the heavy removal of carbon and in which there is a non-hardening ferrite edge, as shown by sample No. 7. Sample No. 5 indicates that even with high silicon, intelligent annealing

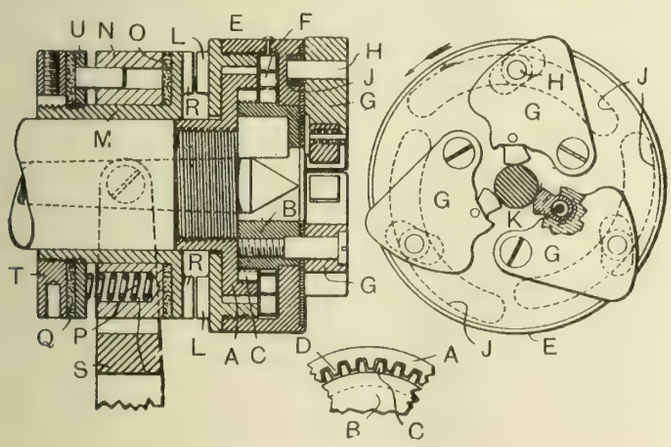
will produce this non-hardening ferrite edge which is absent in most of the samples tested.

Annealing the steel considerably improves its quality, but as the question of cost plays a large part in the plans of many steel foundrymen, I do not think that I should suggest that all steel castings should be annealed. The quality of a good steel casting is so good, even as cast, that due consideration must be given to the work to which a casting is subjected in order that the advantages of annealing may not be counterbalanced by the increased cost of manufacture. Where possible, however, a short annealing treatment to release casting stresses is almost necessary. A muffle treatment of from two to six hours' duration, according to size and section, at 900 to 960° C., and cooling slowly in sand or lime, will meet this requirement. This treatment, however, must not be confused with annealing, as no great alteration to the physical properties must be expected by its use. The main value of annealing, of course, is in the alteration of structure, which produces the change in physical properties.

Where oil quenching is resorted to, it is advisable that such treatment be followed by a tempering treatment. The lead bath is the most effective method for this operation, and five hours at a temperature of 550° to 570° is a suitable treatment.

PRATT & WHITNEY'S LATHE CHUCK.

THE accompanying illustrations show a design of lathe chuck in which the gripping means can be adjusted by the driving power of the lathe while the latter is running so as to release the work being operated on or to fit work varying in diameter, the invention of Messrs. Pratt & Whitney, 111, Broadway, New York. The driven member B, which is approximately in the form of a ring, carries the jaw mechanism and has peripheral teeth C which co-operate with the internal teeth D on the driving member A. There is a meshed relation between the two sets of teeth, and although it is a very free or loose one, it is sufficient to transfer power from the driving to the driven member. The annular driven member therefore



PRATT & WHITNEY'S LATHE CHUCK.

floats, being capable of radial movement in all directions with respect to the driving member. The barrel E houses the driving and driven members A and B and is capable of turning relatively thereto. Between the front edge of the driving member A and the front wall of the barrel E a coiled spring F is disposed, one end of which is rigidly connected with the driven member B exteriorly thereof, while the other end is connected in like manner with the inner surface of the barrel E, this spring constituting a convenient means for closing the jaws of the chuck. The constant tendency of the coiled spring F is to move the barrel E in the direction of the arrow shown and thereby through the cam slots J or their walls which act on the studs H, serving to swing the three jaws G inwardly to close them. The barrel E normally rotates with the driven member B, but it will be apparent that by arresting the motion of the barrel with the driven member, the jaws G will be opened and means are provided for accomplishing this result. The jaws G are provided at their gripping portions with spring-controlled auxiliary jaws K which are pivoted to the main jaws and which have eccentric surfaces for directly engaging the work so that in the case of a lathe, where the work is to be turned, these auxiliary jaws are automatically tightened upon the work. To open the jaws G a sleeve M loose on the spindle is shifted to bring the projections R and L into contact. The sleeve M is held against rotation to a degree determined by springs P and friction washers O and Q, the ring N being held against rotation by its connection to the control lever S. The frictional resistance exerted by the two washers O and Q is greater than the force of the spring F, so that when the projections R arrest the projections L, the jaws G will be fully opened, but when the jaws have been opened to their maximum extent and when the studs H have encountered the end walls of the cam slots J, the sleeve M and collar T will slip on the leather washers O and Q and therefore turn with respect to the ring N and disc U, the jaws G remaining open. The instant the projections R are moved out of engagement with the projections L, the jaws G will be closed by the spring F.

HARDENING HIGH-SPEED STEEL.

THE Vanadium-Alloys Steel Company, Pittsburg, is distributing the following directions for hardening high-speed steel.

When heating for forging, the tool should first be heated very slowly to medium red, after which the tool may be heated to a good forging heat and forged. Avoid hammering the steel after it cools below a good red.

When heating for hardening, preheat very slowly to about 1,500 Fah., and then bring up quickly to 2,250 or 2,350° Fah., according to class of tool. The higher the heat, the better the tool. The steel should look perfectly white at the proper temperature. Quench in oil (or in melted lead). Draw the temper on lathe and similar tools to 950° Fah., or a visible red in the dark.

For lathe and planer tools, the best fire is one made of hard foundry coke in an ordinary blacksmith forge, with a few bricks laid over the top to form a hollow fire. The bricks should be thoroughly heated before the tools are hardened, and the points of the tools should be kept from contact with the fuel this will prevent burning the edges of the tools.

Milling cutters and similar tools should be heated as hot as practicable. Electric and gas furnaces, designed for high heats, will do very satisfactory work in hardening this class of tools, especially those made for hardening high-speed steel. Where a furnace is not convenient, these tools may be hardened in a forge fire, but care must be taken to keep the tool from contact with the fuel.

When cooling, high-speed steel can be immediately quenched in oil, if intended for milling cutter, tap, die, or similar tool. Draw the temper of this class of tools to about 900° Fah. If it is a lathe or planer tool, the point can be cooled in oil and the tool finally cooled in a strong air blast, or if found necessary, oil not being available, the whole tool may be cooled in a strong air blast immediately after having the high heat, or it may be cooled in the open air. For many general purposes, it is found that where tools have been given the extreme high heat and properly quenched, the cutting qualities are improved and the steel extremely toughened if the temper is drawn to a very low red in the dark, and the tool permitted to cool.

It is recommended to (1) remove all scale, and clean free from oil, grease, &c. Then while the tool is perfectly cold, immerse in water and while the tool is wet, roll in powdered boric acid. (2) Place a piece of clean sheet iron in the bottom of the furnace so that the tool will not come in contact with the firebrick. Everything must be kept as free from foreign matter as possible. (3) Preheat slowly to about 1,200° Fah., remove the tool from furnace at this heat and again roll in the powdered boric acid. This completely covers the tool with a coating of boric acid and protects the surface from any decarbonising action of the air. Then, bring up quickly to 2,300° Fah., and cool in oil bath.

In classes of tools where it is advisable to draw the temper best results are obtained if the drawing temperature is 900° Fah., and the tool be permitted to cool in the open air. The boric acid coating that remains can be removed by soaking a short while in fresh cold water. Great care should be taken that the tool is perfectly cold before being immersed in water to remove the boric acid, otherwise the tool may crack. These instructions particularly apply to the hardening of milling cutters, twist drills, taps, dies, &c.

In many cases, a roughing tool will give greater service if heated to 2,300° Fah. and dipped in oil; then when cold, reheat or draw to 1,065° and cool in the open air.

THE MEASUREMENT OF VISCOSITY AND A NEW FORM OF VISCOSIMETER.*

BY H. C. HAYES AND G. W. LEWIS.

IN determining the lubricating properties of an oil, the viscosity test is considered of great value, since by means of this test a good oil can readily be distinguished from a poor one. It is therefore very important that the engineer be able to measure the viscosity of an oil and also the variation of viscosity with temperature. The present paper, dealing with the measurement of viscosity, gives in part the results of a somewhat extended research on the lubricating properties of oils. It is to be followed by a paper giving the relation between the lubricating properties of oils and some easily measurable physical properties.

VISCOSITY.

Matter in all states exhibits a gradual yielding to tangential forces which tend to change its form. This pro-

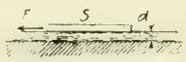


FIG. 1 CONCEPTION OF VISCOSITY

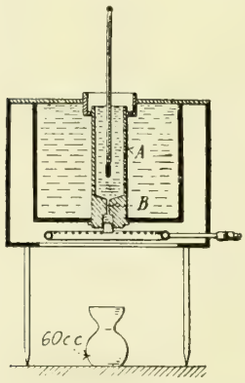


FIG. 2.—SHORT CAPILLARY TYPE VISCOSIMETER.

perty is termed viscosity and may be defined quantitatively as tangential force per unit area divided by shear per unit time. To gain a clear physical concept of this definition, consider a plane surface, Fig. 1, of area S, parallel to and at a distance d from another large plane surface, and the intervening space filled with a liquid whose coefficient of viscosity is η. If a given force F, acting on this plane, is applied to S, the surface will be dragged along and will finally attain a steady velocity, which denote by V. In accordance with the above definition, the relation between these various factors would then be

$$\eta = F/S \div V/d \text{ or } \eta = F \,.\, d \div S \,.\, V \qquad [1]$$

the value of η depending on the units in which these various factors are measured. If absolute values are desired, the factors on the right-hand side of the equation are to be measured in C.G.S. units; but if relative values will suffice, as is the case in nearly all engineering work, they may be measured in any units.

It must be borne in mind that equation [1] is not true when the velocity V is changing, for then only a part of the force F is used to overcome viscosity, a part being used in giving accelerated motion. Under such conditions, another term must be added to this equation. The nature of this term is not difficult to see, for let equation [1] be written $F = \eta \,.\, S \,.\, V/d$. When there is accelerated motion, the force F will be divided into two parts, the part used to overcome viscosity and that used to give accelerated motion. Call these parts f_1 and f_2 respectively, then at any instant $F = f_1 + f_2$, where $f_1 = \eta \,.\, S \,.\, V/d$ and $f_2 = M \,.\, dV/dt$, where M is the mass that is being accelerated and dV/dt is the average change of velocity per second of this mass. The complete instantaneous equation thus becomes

$$F = \eta \,.\, SV/d + M \,.\, dV/dt \qquad [2]$$

and the viscosity cannot be found from this equation unless the last term can be evaluated, which is usually difficult and often impossible.

* Paper presented at the spring meeting of the American Society of Mechanical Engineers, New Orleans, La., April, 1916.

DEVELOPMENT OF A WORKING FORMULA.

In most physical measurements, comparative values are more easily obtained than absolute values. As a result measurements are made in terms of some standard, the absolute value of which has been determined by a more or less laborious process. In making measurements of viscosity, the standard usually chosen is water at a temperature of 20° C. Girard and Poiseuille, by studying the flow of liquids through capillary tubes, were the first to measure the absolute value of viscosity with anything like accuracy. On the basis of his excellent experimental work on the viscosity of water, Poiseuille deduced the formula

$$V = K \,.\, D^4 \,.\, H/L$$

where V = volume of liquid transpired
L = length of capillary
D = diameter of capillary
H = pressure
K = constant for each liquid at a given temperature.

Later, this empirical formula and its corrections were proved by several investigators. By assuming there is no slip at the surface of the capillary, that the liquid flows steadily without eddies or turbulent motion, and that there is no kinetic energy of efflux, then the transpiration formula for a liquid flowing under its own head becomes

$$\eta = \frac{\pi}{8}(hgr^4/lv)\,\rho t$$

where η = coefficient of viscosity (often contracted to viscosity)
h = liquid head
g = acceleration of gravity
r = radius of capillary
l = length of capillary
v = volume of flow
t = time of flow
ρ = density of liquid.

Experiment shows that the first assumption is true if the

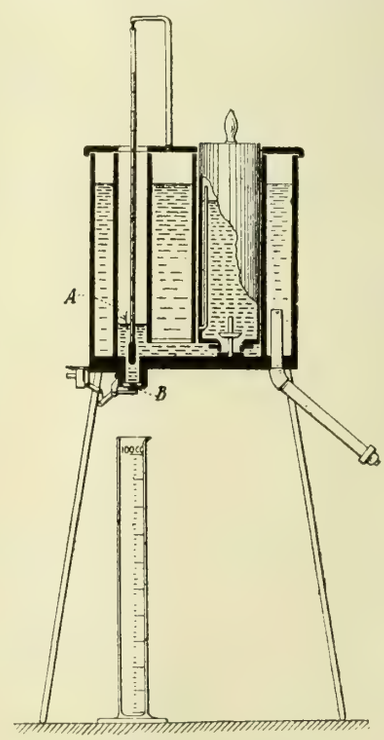


FIG. 3.—ORIFICE TYPE VISCOSIMETER.

liquid is one that wets the surface of the capillary. The work of Reynolds shows the second assumption is true if the velocity of the liquid through the capillary is kept less than $700 \,.\, \eta/\rho \,.\, r$ cm. per second. The third assumption, of course, can never be true. The liquid must have kinetic energy when it leaves the capillary. In accordance with equation [2], a correction term must be added which, according to Couette, Finkener, and Wilberforce, should be $-v\,\rho/8\pi lt$. The complete expression for the viscosity is therefore of the form

$$\eta = \rho\,(A \,.\, t - B/t)$$

where A and B are constants for any piece of apparatus, ρ and t are the density and time of flow, respectively.

After a thorough examination of the recorded data on the viscosity of water, Knibbs concluded that the correct formula should be

$$\eta = \pi h g r^4 \rho t / 8 l v - 1.12 v \rho / 8 \pi l t$$

It is to be noted that the correction term is larger than that given by Couette. Moreover, this correction term varies with the time of flow, approaching zero when the velocity of flow is very slow, in which case t becomes very great. The value of the term increases with the temperature of the liquid since the time of flow decreases, and so the percentage of error in

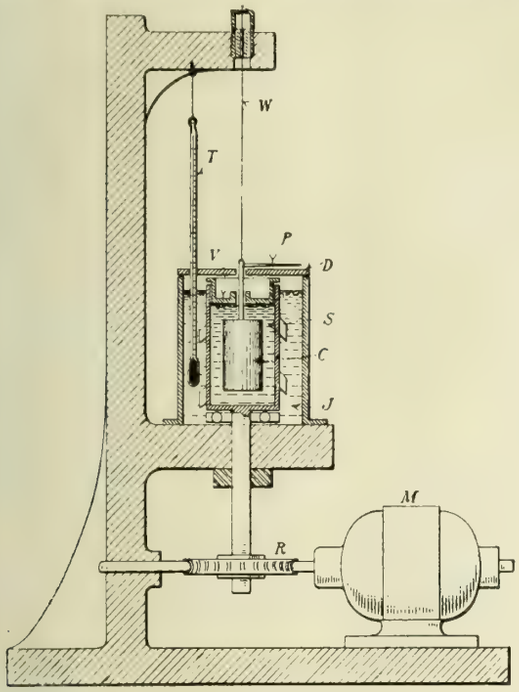


FIG. 4.—THE NEW VISCOSIMETER.

a viscosity vs. temperature curve due to neglecting this correction factor will increase abnormally toward the higher temperatures. This is due to two causes, the correction to be applied increases with the temperature and the value of the quantity to be corrected decreases rapidly with the temperature. Attention will be called to this fact when some of the various comparative methods are discussed. It is further to be noted that this correction term varies inversely as the length of the capillary. A short capillary requires a large correction term.

This formula, as corrected by Knibbs, has been submitted to careful experimental test by Hosking, and by Bingham and White. These investigators have determined the constants of the formula experimentally and have obtained fair agreement with theory. The capillary tube method, as employed by these experimenters, though complicated and laborious, can be depended upon for giving absolute values of the viscosity, and the accuracy of any viscosimeter can be determined by a comparison with the results obtained by this method.

CLASSIFICATION OF VISCOSIMETERS.

Class 1. *Short Capillary.* In meters of this type the liquid to be tested is forced either by gravity or by pressure through the capillary and the viscosity is determined in terms of the time required for a given volume to pass through the meter, as compared with the time required for a standard liquid to discharge the same volume. A cross-section of a meter of this type is shown in Fig. 2. The essential parts of the instrument are a cylindrical bowl A in which the oil is placed and a short capillary tube B through which it is discharged. The instrument must have temperature controlling and measuring devices, means for starting and stopping the flow and volume and time measuring apparatus.

To this class belong the Saybolt meter, adopted as a standard by the Standard Oil Company; the Engler meter, adopted as a standard by the United States Government and Germany; the Redwood meter, adopted as a standard in England; the Scott meter; and the pipette, adopted as a standard by the Pennsylvania Railroad and much used by chemists. The majority of the viscosimeters on the market are of the short capillary type.

Class 2. *Orifice.* This type employs an orifice in place of the short capillary of the previous type. Fig. 3 is a section of such a meter, in the cylindrical bowl A of which the oil to be tested is kept at constant head above the orifice B. The Carpenter meter belongs to this class.

Class 3. *Dropping a solid body through a tube filled with the liquid*, the solid body being usually a sphere or a plunger. Meters employing this principle determine the viscosity in terms of the time required for the body to drop a certain distance through the liquid, as compared with the time required for the same body to drop through a standard liquid. To this class of meters belong the Perkins meter, which employs a plunger and vertical tube, and the Flowers meter, which employs a small steel sphere and a slanting tube.

Class 4. *Oscillating Disc or Cylinder.* These meters determine the viscosity in terms of the damping which the oscillating disc or cylinder experiences when placed in the liquid as compared with the damping when placed in the standard liquid. The Doolittle meter is an example of this class.

Class 5. *Rotating Disc or Cylinder.* This type determines the viscosity in terms of the speed of rotation of the disc or cylinder in the liquid under test as compared with the speed of rotation in the standard, the driving torque remaining constant. The Stormer meter is an example of this class.

DISCUSSION OF THE VARIOUS TYPES.

The paper here enters into a discussion of the value of each of the above types, so far as accuracy is concerned. It enumerates the following errors and indicates their causes and magnitudes:

Acceleration error. In all meters of Classes 1 and 2 the acceleration term ($M \cdot dV/dt$) is neglected since its evaluation is impossible. This introduces an acceleration error.

Surface tension error introduced in all flow types due to difference in surface tension of the standard liquid and the liquid under test.

Critical velocity error. A source of error in most capillary and orifice forms is that the dimensions of the instrument are such that for the standard, water, the flow exceeds the critical velocity and the resultant turbulent flow makes the value of t abnormally large.

These three errors are prominent in all meters named above as standards and cause the viscosity as given by these meters to be much too low. The constant speed of rotation which a disc or cylinder immersed in a liquid will attain under

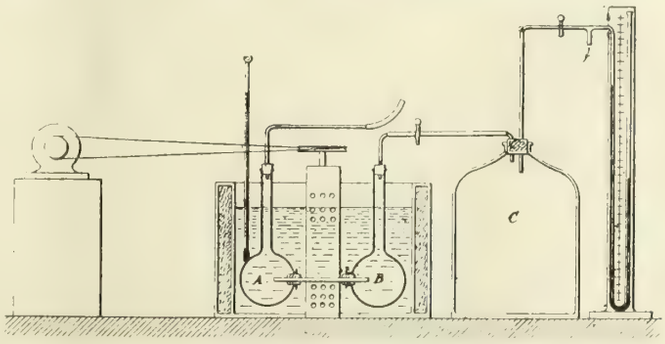


FIG. 5.—CAPILLARY TUBE METHOD.

the action of a constant torque is a true measure of the viscosity of the liquid. The Stormer viscosimeter attempts to operate in accordance with this principle, but the friction of the moving parts is necessarily such that a constant torque cannot be obtained. With proper refinement, this meter could be made to give good results. The fact that a meter based on this principle can theoretically give accurate results has led to the development of a new viscosimeter now to be described.

THE NEW VISCOSIMETER.

This viscosimeter operates in accordance with the principle that a solid body having a surface of revolution experiences, when suspended in a rotating liquid, a torque which is proportional to the viscosity of the liquid. The instrument is

shown diagrammatically in Fig. 4. The specimen S is contained within a cylindrical chamber which is caused to rotate uniformly by a motor M through a worm drive R. A cylinder C is suspended within the specimen by a thin steel wire W, so that the axis of the rotating liquid coincides with the axis of the cylinder. The specimen chamber is provided with a cap V so shaped that the excess liquid can overflow when the cap is seated and thus give constant conditions within the chamber. The specimen chamber is surrounded by an oil jacket J in which a thermometer T is suspended. The jacket oil may be brought to any desired temperature by means of a heating coil, or a side coil not shown in the diagram. The cover D of the jacket chamber is provided with a scale which is marked in degrees or may be calibrated to read off directly, through the deflection of the pointer P, the

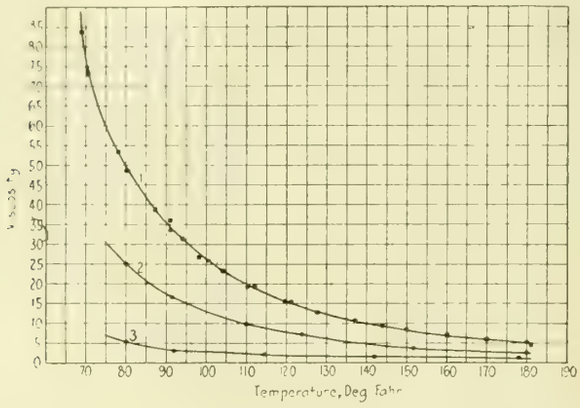


FIG. 6.—VISCOSITY CURVES FOR MEDIUM GAS ENGINE OIL.

viscosity in terms of a standard liquid. The specimen chamber and the suspended cylinder are both made of copper to ensure constant temperature throughout the specimen, and the outside of the specimen chamber is provided with blades which keep the jacket oil thoroughly mixed as the chamber revolves and thereby exposes the latter to a uniform temperature. This is an important factor toward ensuring constant temperature throughout the specimen.

The experimental work has shown that the temperature of the specimen is uniform to within a small fraction of a degree. Moreover, the temperature of the specimen follows the temperature of the jacket oil so closely that the temperature-viscosity curve can be taken while the temperature is slowly raised or lowered. This proves to be a great saving of time. It also saves labour, for one does not need to stand by the instrument continually. The deflection of the pointer is at

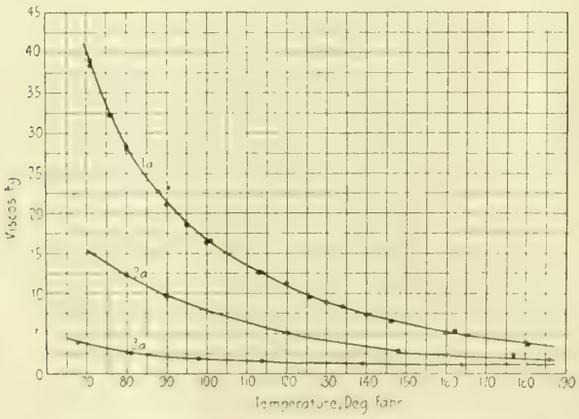


FIG. 7. VISCOSITY CURVES FOR LIGHT GAS ENGINE OIL.

any instant a measure of the viscosity, so all that is required is to take simultaneous readings of temperature and deflection at intervals during the heating or cooling process.

EXPERIMENTAL RESULTS.

To test the accuracy of this viscosimeter, the temperature viscosity curve was found for a light and a medium gas engine oil by the capillary tube method, the apparatus for which is shown in Fig. 5. The oil was drawn from vessel A to vessel B and vice versâ by connecting each in turn with the partial vacuum chamber C. These vessels were submerged in a thermostat which could be maintained at any desired temperature. The results, in terms of the viscosity of water at 20° C., are given by the points enclosed in circles for curves 1 and 1a, Figs. 6 and 7, the latter referring to the lighter oil. The viscosity of these same oils as given by the new meter is represented on curves 1 and 1a by the points enclosed in squares. The agreement between the two methods is almost perfect.

The viscosity of these oils as given by a meter of the short capillary type, Fig. 2, is given in curves 2 and 2a. Curves 3 and 3a give the viscosity of these oils as obtained with a meter of the orifice form, Fig. 3. As predicted, the results given by the short capillary type are much too low (on the oils tested about 100 per cent. too low) and the results given by the orifice type are still lower.

CONCLUSIONS.

The errors inherent in all flow types of viscosimeters have been predicted and the predictions verified by experiment. The magnitude of the errors are such that these meters cannot be depended on for giving even approximate results. The various meters of this type on the market do not give results which are in agreement, and no one of these meters can justly be claimed as a standard.

The new viscosimeter of the non-flow type described has the following advantages:

(1) It gives values for the viscosity which are in agreement with those given by the standard capillary tube method.

(2) During a series of tests at various temperatures, the oil is not handled.

(3) The sensitiveness of the instrument can be made anything desired by changing the speed of rotation of the specimen or by using suspension wires of various diameters.

(4) The density or change in density is not a factor in computing the results, in fact the instrument may be graduated to read off the viscosity directly.

(5) The viscosity of liquids which contain particles in suspension can be measured, and the operation of the meter is independent of the colour of the specimen.

(6) The temperature-viscosity curve can be taken with a fair degree of accuracy while the temperature is rising or falling, as the temperature of the specimen follows the temperature of the jacket so closely.

(7) The personal error which arises in determining time intervals with a stop-watch is removed.

(8) The instrument is simple, rigid, and self-contained. It has no separate parts to get lost or glass parts to get broken.

NON-FERROUS ALLOYS FOR LOCOMOTIVE EQUIPMENT.

AT the recent annual meeting of the American Society for Testing Materials, Mr. G. H. Clamer, chairman of the subcommittee on non-ferrous alloys for railroad equipment, presented proposed tentative specifications as follows:—

1. (a) These specifications cover the various non-ferrous alloys for locomotive equipment in ingots, castings, and finished car and tender bearings.

(b) These alloys and the purposes for which they are frequently used are as follows:—

Bearing metal Nos. 1 *and* 2 for connection-rod bearings, bushings, eccentric straps, driving-box bearings, trailer-truck bearings, crosshead gibs, hub liners, and miscellaneous bushings.

Bearing metals Nos. 3 *and* 4 for lead-lined bearings, for locomotive tenders, freight and passenger car equipment.

Bell metal for locomotive bells only.

Steam metal for cocks, valves, water gauge and gauge valves, injectors, and other castings subjected to internal steam pressure.

Red brass for miscellaneous castings for which a red colour is desirable, and which are not intended to resist internal pressures.

Yellow brass for car trimmings.

Brazing metal for fittings and unions for copper pipe.

Babbitt metal for babbitting driving boxes, rod brasses, crossheads, and for hub liners.

Lining metal for lining truck brasses, tender brasses, and car brasses.

CHEMICAL PROPERTIES AND TESTS.

2. (a) The alloys shall conform to the requirements as to

chemical composition, with the permissible variations specified in the accompanying table.

(*b*) Where no figures are given for impurity maximum, these elements may be present up to any amount to come within the total impurity specified, providing the material otherwise meets the chemical and physical tests. Where maximum percentages are specified, the elements referred to are considered as impurities, and shall not be intentionally added.

3. An analysis will be made by the purchaser or his representative from one ingot, casting, or journal bearing representing each lot. The chemical composition thus determined shall conform to the requirements specified in Section 2 for the particular alloy.

4. (*a*) *Ingots.*—Drillings shall be taken with a drill at least ½in. diam. at a point midway between the heaviest and smallest cross-section of the ingot. Ingots having two or more sections, drillings to be taken from each section. In the case of babbitt metal and lining metal, drillings so taken shall be melted in a thoroughly-cleaned ladle with a little resin flux and poured into a piece of thin section. This piece shall be sawed into three parts, and the sawings therefrom thoroughly mixed to constitute a sample for chemical analysis.

(*b*) *Locomotive Castings.*—Drillings shall be taken with a drill as large as possible at such points in the casting as shall be thoroughly representative. Drillings through the skin shall be rejected. Drillings thoroughly mixed shall constitute the sample for chemical analysis.

(*c*) *Car and Tender Bearings.*—Drillings shall be taken with a drill at least ½in. diam., at three points on the bearing selected for the physical test as specified in Section 5 (*b*), as widely separated as possible. Drillings representing the skin of the casting shall be rejected. These drillings, thoroughly mixed, shall constitute the sample for chemical analysis. Drillings shall be taken in a like manner from the lining, exercising care that the drill does not penetrate the soldered surface.

(*d*) All samples, whether taken with a drill or saw, to be kept free of oil and to be magnetised to remove iron introduced in taking the sample.

PHYSICAL INSPECTION AND TESTS.

5. (*a*) *Locomotive Castings.*—The castings shall be sound, free from blowholes, flaws, or shrinkage cracks, and shall show good foundry practice and workmanship. One casting representing each lot of locomotive bearings will be broken by the purchaser or his representative, for examination of fracture. The fracture shall disclose no shrink discoloration, segregation, dross or dirt spots within ⅝in. of the bored journal engaging surface, and shall show no distinct signs of imperfect mixture.

Non-Ferrous Metal Mixtures.

Alloy.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, per cent.	Iron, max., per cent.	Antimony, per cent.	Phosphorus, max., per cent.	Aluminium, per cent.	Sulphur, max., per cent.	Total Impurity including Zinc, per cent.
Bearing Metal										
No. 1	remainder	9-11	9-11	1·5†	0·4	0·5†	...	none	...	1·0
No. 2	,,	7-9	14-16	1·5†	0·4	0·5†	...	,,	...	1·0
No. 3	,,	7-9	14-16	3·0†	0·4	0·5†	...	,,	...	1·0
No. 4	,,	4-6	15-20	5·0†	0·4	0·5†	...	,,	...	1·0
Bell Metal	,,	16-18	0·25†	0·25†	0·25	0·25†	0·02	,,	0·05	0·5
Steam Metal ...	,,	5-7	2-3·5	3·5†	0·25	0·25†	0·02	,,	0·05	0·5
Red Brass	,,	4-6	4-6	4-6	0·40	0·40†	0·02	,,	0·05	1·0
Yellow Brass...	,,	1·5†	1-3	29-33	0·50	0·50†	...	,,	...	1·25
Brazing Metal.	,,	0·5†	0-5†	18-22	0·40	0·25†	...	,,	...	1·0
Babbitt Metal..	0·5†	9-11	remain-	0·10†	0·05	15-17	...	,,	...	0·75
Lining Metal...	0·5†	4-6	der	0·10†	0·05	9-11	...	,,	...	0·75

† Maximum.

(*b*) *Car and Tender Bearings.*—The bearings shall be sound, free from sand, blowholes, flaws, or shrinkage cracks, and shall show good foundry practice and workmanship. One bearing representing each lot will be broken by the purchaser or his representative for examination of fracture. The fracture shall show no shrink discoloration, segregation, dross or dirt spots within ½in. of the bored journal engaging surface. This test shall be made before linings are applied. A second test shall be made after application of the lining as follows: (1) The suspended brass, when tapped with a hammer, shall give a distinct ring. (2) The lining, when chipped with a cold chisel, shall tear from the soldered surface as distinguished from clean shearing.

6. (*a*) *The Ingot.* Each 5,000lbs. or fraction thereof shall constitute a lot. The ingot from which the sample is taken to be included in the shipment.

(*b*) *Locomotive Castings.*—Each 100 castings or fraction thereof, unless otherwise specified, shall constitute a lot. The manufacturer shall furnish, free of cost, one casting representing each lot for the purpose of tests as specified in Sections 4 (*b*) and 5 (*a*.).

(*c*) *Car and Tender Bearings.*—Each 300 bearings or fraction thereof shall constitute a lot. The manufacture shall furnish, free of cost, one bearing representing each lot for purposes of tests as specified in Sections 4 (*c*) and 5 (*b*).

PERMISSIBLE VARIATIONS IN DIMENSIONS.

(For Car and Tender Bearings Only.)

7. (*a*) The purchaser will furnish drawings showing the dimensions of the bearings ordered and permissible variations therefrom and the bearings shall conform to these drawings within such permissible variations.

(*b*) The thickness at the centre of the brass and of the complete bearing shall not vary more than $\frac{1}{32}$in. over or under the normal thickness shown on the drawing. The thickness of the lining shall not vary more than $\frac{1}{32}$in. over or under the normal thickness shown on the drawing.

WORKMANSHIP.

8. (*a*) *Locomotive Castings.*—The castings shall conform to the dimensions specified, and shall show good workmanship generally.

(*b*) *Car and Tender Bearings.*—The bearings shall show good workmanship generally, and shall be free from mechanical imperfections. They shall be bored to a true radius, and with the axis parallel to the plane of the top and perpendicular to the side lugs and bearing flange. The lettering shall be clear and distinct. No emery to be used on journal engaging surfaces on either the brass or the lining.

9. (*a*) *Ingot.*—The manufacturer's marking only shall be required, unless otherwise specified.

(*b*) *Locomotive Castings.*—The lot number and other marks as required by the drawings shall be legibly marked on each casting.

(*c*) *Car and Tender Bearings.*—The name or initials of the manufacturer, the initials of the purchaser, type number, journal size, and lot number shall be legibly cast with raised figures on a depressed surface of each bearing, as shown on drawings.

INSPECTION AND REJECTION.

10. (*a*) Inspection may be made at the manufacturer's works where the ingots, locomotive castings, or car and tender bearings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry at all times while work on the contract is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. Failure to meet the chemical or physical specifications, or non-conformity to any of the foregoing requirements as to permissible variations, dimensions, and markings, constitute sufficient cause for rejection of the lot represented by the sample chosen.

Engineering Research in the United States.—A Bill now before the United States Congress proposes to establish an engineering experiment station in each State for the purpose of carrying on researches, investigations, and experiments looking toward the progress of the industries and industrial arts. The annual sum of £3,000 is to be appropriated for each State engineering experiment station.

ACID-RESISTING ALLOYS.*

BY W. C. CARNELL.

FOR many years various metals and alloys have been offered for which more or less acid-resisting properties were claimed. They had their uses, but as complete acid-resisting materials they were not successful. With the advent of fused silica a decided advance was made, and it successfully replaced platinum in a number of processes.

Fused Silica, Feralun, and Ferrochrome.—In 1911 a basin of fused silica was tried out at the factory with which the writer was connected; so successful were the results that a 10-ton cascade concentrating plant for sulphuric acid was erected to replace a platinum outfit. The results were all that could be desired. The acid made was even better than that made in platinum. Fused silica is brittle and costly and must be handled with as much care as glass.

In 1913 a material under the trade name of Feralun was tried out. This was a mixture of cast iron and an abrasive, the abrasive being an alloy of aluminium and silicon. The surface of the iron was covered with the abrasive. The abrasive was acid-resisting, but the acid soon destroyed the iron, leaving a porous mass. We, however, found Feralun useful for nipples on acid tank cars.

Fused silicon has acid-resisting properties that are all that could be desired for sulphuric acid, but it is more brittle than fused silica, and its use has not been very extensive. Ferrochrome is a very promising product. Glacial acetic acid does not attack it; 56 and 28 per cent. acetic acid attacks it slightly. Strong and weak nitric and sulphuric acids have practically no effect on the alloy. Hydrochloric acid attacks it readily. The experiments were carried out in a bowl 18in. diam. and 6in. deep.

Silicon-Iron Alloys.—The materials thus far mentioned are valuable for specific purposes. The real dawn of acid-resisting alloy came with the use of silicon-iron alloys. The beginning of the use of these alloys was about six years ago. The first advertisement the writer observed of this alloy was in the "Journal" of the Society of Chemical Industry, January 15th, 1912. This was a silicon-iron alloy, Tantiron, introduced by the Lennox Foundry Company, Ltd., of London, England.

In May, 1912, after a year of experimenting, the first silicon-iron alloy in the United States was put on the market under the name of Duriron, by the Duriron Casting Company, of Dayton, Ohio. Ironac is another trade name for a silicon-iron alloy made by the Houghton Company, Ltd., of London, England. While these are all alloys of iron and silicon, their composition is not the same.

Silicon-iron alloys, as put out under the above names, are very resisting to all strengths of sulphuric acid, and apparatus made of this alloy is used in all forms of concentrating vessels and cooling devices for the concentration of this acid. By the use of the so-called cascade basins, set in a proper furnace, full strength oil of vitriol is made from 50° acid. If all the fittings and coolers are made from this alloy the resulting oil of vitriol is practically free of iron after the plant has been in operation a few weeks. Where brimstone acid is used the resulting oil of vitriol should not contain over 0·0002 per cent. iron. For sulphuric acid concentration, the alloy is durable and the breakage is very small. A plant properly handled will run for months without a shut down. The success of the modern tower system for concentrating sulphuric acid has been due largely to the use of pipes and fittings made of this alloy.

Silicon-iron alloy castings have extensively replaced stoneware parts for the manufacture of nitric acid. Early in 1915 the demand for nitric acid increased to enormous proportions; extensions to old nitric acid plants and the erection of new and larger plants was immediately demanded. The capacities of the stoneware factories of the country were soon taxed to their limit. Deliveries could not be made under six months, if at all; had the production of nitric acid been dependent upon stoneware as it was a few years ago, the production of nitric acid would have been greatly curtailed and the story of the great war would probably be different.

The silicon-iron alloy is resistant to nitric acid of various strengths. It can be cast into all the various forms required for nitric acid apparatus. Castings can be made as readily and as quickly as can those made of cast iron. Here was the ideal substitute for stoneware. Necessity compelled its use and to-day it has largely superseded stoneware for nitric acid production.

Duriron in a Nitric Acid Plant.—A large nitric acid plant equipped entirely with this alloy in the form of Duriron was in service for eight months; the alloy showed no indications of corrosion or deterioration. There was practically no breakage. Fire destroyed the building housing of the plant and most of the supports for the apparatus. It did not harm the castings, though they were exposed to intense heat, and 80 per cent. were recovered, put into service, and are in use at the present time. Ninety per cent. nitric acid made in a plant equipped with Duriron castings showed an average iron content of 0·0014 per cent. iron, while 36° nitric acid (52·30 per cent.) showed 0·0042 per cent. iron.

The silicon-iron alloy was developed to resist acid. It not only resists acid, but it is resistant to corrosion and to rust. Ground surfaces, representing the true alloy, are practically immune from rust. The rough casting may show some rust on exposure, but this is due to impurities in the surface, caused by contact of the alloy with the moulding sand; this is a surface rust only and will not penetrate. The alloy is also heat resisting, when made of suitable design. The walls must not be too thick for very high temperatures. Castings do not distort on heating, but hold their form up to the melting point. The composition properties of Duriron are as follows:

Silicon	14·00 to 14·50 per cent.
Manganese	0·25 to 0·35 per cent.
Total carbon	0·20 to 0·60 per cent.
Phosphorus	0·16 to 0·20 per cent.
Sulphur	Under 0·05 per cent.
Melting point	2,500° to 2,550° Fah.
Specific gravity	7·00
Compression strength	70,000lbs. per square inch
Tensile strength	25 per cent. less than cast iron

A bar of Duriron was compared with a bar of equal size of the best grade of chemical pottery, under equal conditions, the earthenware test bar broke so quickly that the testing machine gauge did not record any pressure. The Duriron bar broke under a load of 1,000lbs. By using a suspended vessel on an earthenware bar and gradually loading it with small pieces of metal and sand, a breaking test of 100lbs. was obtained for the earthenware bar.

Tantiron and its Properties.—Tantiron was first produced by Robert W. Lennox, of the Lennox Foundry Company, of London, England, about 1908. In 1913 the rights for the use of this alloy in the United States, Canada, and Mexico were acquired by the Bethlehem Foundry and Machine Company, of South Bethlehem, Pa. An approximate analysis of the properties of Tantiron is as follows:

Silicon	14·00 to 15·00 per cent.
Sulphur	0·05 to 0·15 per cent.
Phosphorus	0·05 to 0·10 per cent.
Manganese	2·00 to 2·50 per cent.
Carbon (graphite)	0·75 to 1·25 per cent.
Melting point about	2,550° Fah.
Specific gravity	6·8
Tensile strength	6 to 7 tons per square inch

In general silicon-iron alloys cannot be cast in rectangular shapes or flat surfaces. The chemical engineer should collaborate with the foundryman in order to design shapes which can be produced in the foundry and still serve the purpose of the operating conditions required. The alloy is not suitable for apparatus in which high internal pressures are to be used unless it is protected by a protecting jacket. Forty to fifty pounds is given as the maximum pressure for an autoclave made of Tantiron.

Conclusions.—While there is still opportunity for improvement, and while there is much more to be desired in an acid-resisting material out of which to construct apparatus for the acid industry, yet the silicon-iron alloy or silicide of iron, as it has been called, has proved a boon to the acid industry, and without which many things could not have been accomplished. It is more efficient than stoneware. At best, chemical stoneware, if made properly, should take 10 to 12 weeks for its production. Castings of this alloy can be made

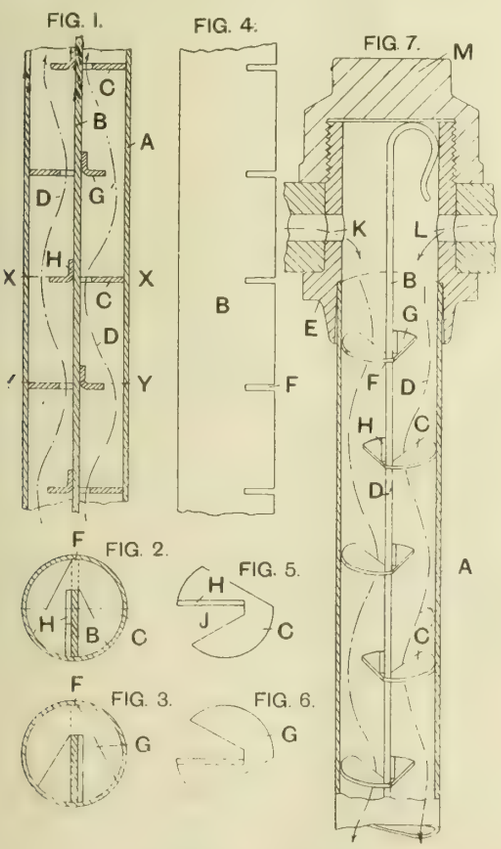
* Abstract of paper read before the American Institute of Chemical Engineers, June 16th, 1916.

and delivered in the same time it takes to make castings out of cast iron.

The limitation to castings of this alloy are shop and foundry limitations only. One company has a foundry with a furnace capacity of 72 tons per day. To day thousands of tons of castings made of this alloy are in use. It is finding its way into all branches of the chemical industry. Since its introduction new chemical processes have been started which were impossible before because of lack of suitable apparatus. Silicon-iron alloys are being improved rapidly and the time does not seem far distant when all sorts of vessels will be made of this or a similar alloy that will give to the chemical industry the ideal non-corrosive material that may be fabricated into all the shapes peculiar to the needs of the industry.

HEAT-TRANSMITTING TUBES FOR EVAPORATORS.

To increase the efficiency of the heat-transmitting tubes for evaporators Messrs. Watson & Billetop, High Bridge Works, Walker Gate, Newcastle-on-Tyne, propose in a recent patent to arrange a carrier plate adapted to form a longitudinal medial division plate in the tube dividing the flow of fluid into two streams and adapted to carry a series of baffle plates alternately arranged so that successive plates are of opposite hand, whereby each of the two streams is zig-zagged and effectively baffled by the one set of plates. Fig. 1 is a longitudinal section of a tube fitted with a carrier plate and baffles. Fig. 2 is a transverse section on the line X of Fig. 1. Fig. 3 is a view



TUBES FOR EVAPORATORS.

similar to Fig. 2 taken on the line Y of Fig. 1. Fig. 4 is a view of the carrier plate, and Figs. 5 and 6 are views of the reversely set baffles. Fig. 7 is a conventional perspective section showing the baffles in position in the tube. The tubes A are fitted with a carrier plate B of width equal to the diameter of the tube and this plate is notched at F. The baffles C and G are shaped as shown in Figs. 5 and 6, which show them reversely set; the baffles are all the same shape, but alternate sets are oppositely disposed as shown in Figs. 1 and 7. The baffles are held in position by being fitted into the notches F of the plate B, and are attached thereto by means of the lugs H, which are turned up when forming the vee notches J in the baffles. The plate B divides the fluid passing through the tube into two streams, and the alternate arrangement of the baffles cause each stream to take a zig-zag path as shown by the dotted chain line D. Fig. 7 shows the tube connection E fitted with ports K and L and with a coupling nut M. Upon removal of this nut the plate B can be withdrawn, with the baffles in position, by means of the handle shown.

THE SELECTION OF FORGING MACHINES.*

MANY forge shops have unbalanced equipment, and managers who attempt to undertake general contracting without the proper machines for the various classes of work offered in the open field of competition usually get into trouble. It may be desirable to have but one type of machine in a shop, but in such cases the forging manager should not consider every job a prospect. He cannot meet a competitor's price unless his shop is properly equipped. In the concrete examples of forging costs which are given in this paper, only three types of machines will be considered, steam hammers, board hammers, and upsetters.

Three items are to be considered in figuring the cost of a forging—material, direct labour, and overhead expense. The material is considered from the standpoint of the gross weight of steel required to make a certain forging. The direct labour is considered to be the actual productive labour work on the forging, consisting in every case of the forger himself, and, in some instances, of the heater, trimmer man, and grinder, where these other men are required for the work.

The overhead expenses will be considered as varying directly as the productive labour. In this may be included insurance and taxes, office expenses, sales expenses, interest and discount, &c. These items are considered as not varying with the unit used except as this unit might affect the actual productive labour. The cost of heating, steam, or electric power, depends upon the unit used. The life of dies is very greatly influenced by the type of machine used. The upkeep of the different machines also varies greatly, as do the number and value of the repair parts which must be purchased from time to time.

Turning now to a concrete example, consider a flange or disc, weighing about 4lbs. The first column of data below indicates the machine used to make the forgings. The second column gives the hourly production. The third column shows the number of men used, consisting in each case of the forger and one or more helpers. The fourth column shows the gross weight of steel used, expressing the board and steam-hammer weight as 100 per cent.

Machine.	Production.	Men Used.	Gross Weight Per Cent.
Board	70	2	100
Steam	90	2	100
Upsetter	140	3	75

From the standpoint of production, the steam hammer appears to be only a trifle better than the board hammer; but since the labour for a board hammer operation is cheaper than for a steam hammer, it is evident from a standpoint of productive labour that a board hammer and a steam hammer are about on a par in this instance. The overhead in the case of a board hammer is, however, materially lower from a purely operating standpoint. The cost of power used by board hammer is less than the cost of the steam used by the steam hammer. The upkeep on a board hammer and the repairs are also usually less than on a steam hammer. We also have found that in most instances the life of the dies is greater when used in a board hammer than when used in a steam hammer. It is, therefore, evident that if a man had no upsetter in his plant it would be most economical to make these forgings on a board hammer. Turning to the upsetter, it is noted that, although an extra heater is required, the production is double that attained from the board hammer, so that from a standpoint of production the upsetter is more desirable than either of the other units for this particular

* Abstract of paper read before the American Drop Forge Association

work. The 25 per cent. saving in weight further indicates that the proper machine for this work is the upsetter.

We have not given actual costs because rates vary in different localities. Overhead varies greatly in different localities. The value of the weight-saving depends entirely upon the price of the steel used for this work. This saving in weight must be compared with the labour and overhead costs. With these figures any forge man knowing his own rates and overhead, and with any paid cost of material, may immediately figure what the saving would be.

Some very interesting results occurred in connection with the forging of three small transmission gears, weighing about 1½lbs. to 2lbs. each. At one time all these forgings were made under the steam hammer; they are now being made on a board hammer. The labour costs are practically identical with both styles of hammers, but the die costs, including the rates, were very different in the two cases. The data are as follows:—

Pieces Made.	Total Die Labour.	Die Labour per 1,000 Pieces.
Steam Hammer.		
41,769	£258·92	£6·20
39,922	261·25	6·53
37,301	229·11	6·15
Board Hammer.		
78,427	£197·79	£2·50
72,641	169·95	2·30
80,914	159·45	2·00

Many forge men realise that there is a difference in the life of dies in the case of board and steam hammers, but it is seldom that it can be forcibly illustrated as in this instance.

Another interesting comparison from a cost standpoint was made with a transmission gear, weighing about 2lbs. The data follows:—

Machine.	Men Used.	Production Per Man.	Gross Weight. Per Cent.
Steam	2	100	100
Upsetter	3	160	73

It is evident that the improvement in production effected by the upsetter is not so great in this case as it was in the previous instance, and a question would arise as to which unit would be the better to use for this piece. If the cost of the upsetter men were low it is evident the upsetter would be the proper unit, particularly if the steel used were expensive. The die costs probably would be lower in the case of the upsetter, so that in most shops it would probably pay to do this work on this unit.

METAL QUOTATIONS.

TUESDAY, AUGUST 29TH.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled..	1/3¾ per lb.
,, tubes (brazed)	1/5 ,,
,, ,, (solid drawn)	1/3 ,,
,, ,, wire	1/2⅞ ,,
Copper, Standard	£110/–/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£32/5/– ,,
,, Foreign (soft)	£30/15/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	31 13/16d. per oz.
Spelter (American)	£45/–/– per ton.
Tin, block	£173/–/– per ton.
Tin plates, I.C.	32/– per box.
Zinc sheets	£72 per ton.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Automatic couplings for railway cars. Serguienko. 6676.
Differential-pressure gauge. Soc. Blot Garnier et Chevalier. 6792.
Two stroke-cycle explosion engine. Bonfa. 7943.
Core-making machines for foundry purposes. Warren, Valentine, and Leyland Motors (1914), Ltd. 9990.
Systems of railway signalling and train controlling. Bound and Rowland. 11272.
Rotary cylindrical valves for internal combustion engines. Fountain & Langford. 11491.
Internal combustion engines. Ruston & Chorlton. 11543.
Explosion engines coupled to dynamos. Soc. Anon. des Etablissements L. Bleriot. 11566.
Preparation of peat for fuel. Paterson. 12003.
Multiple spindle turning lathes. Berry. 12016.
Hydraulic machinery for the manufacture of superheater elements. Portham & Waite. 12076.
Ignition systems for internal combustion engines. Randolph. 13391.
Means for separating water from air or steam. Mortimer. 13599.
Internal combustion engines. Booth. 14062.
Power propelled vessels. Smith. 14260.
Internal combustion engines. Fergusson. 14819.
Valve mechanism of internal combustion engines. Carlson. 15059.
Fire-bars for furnaces. Chadwick. 16268.
Ball cages for ball bearings. Soderlund. 16352.
Construction of variable speed gear. Brooks. 16397.
Propellers. Lowe. 16521.
Substitute for packings, and stuffing boxes. Gelpi. 17891.

1916.

Lathes. McCurd, W. A. 347.
Chucks for lathes. Gordon, H. 3664.
Internal-combustion engines. Gile, F. H. 4065.
Ignition controllers for internal-combustion engines. Kennington, W. O. 5680.
Reversible rotary pumps. Selson Engineering Company, and Goodwin, H. 6265.
Apparatus for controlling and stopping trains independently of drivers. Bound, A. F., and Rowland, W. 6989.

ELECTRICAL, 1915.

Dynamos. U.S. Light and Heat Corporation. 11510.
Manufacture of incandescent electric lamps. British Thomson-Houston Company. 11544.
Electrical transformers. Schaanning & Harlow. 11568.
Short circuiting and brush-lifting gear for alternating-current motors. Lancashire Dynamo and Motor Company, Whitmore, and Roberts. 11790.
Electrical measuring instruments. Foster. 14214.
Contact making and breaking devices of magneto electric machines. Conner. 14995.
Electric insulators. Muller. 16185.
Electric batteries. Marks. 16540.
Rotary interrupter for electric ignition devices. Robert Bosch (Firm of). 17921.

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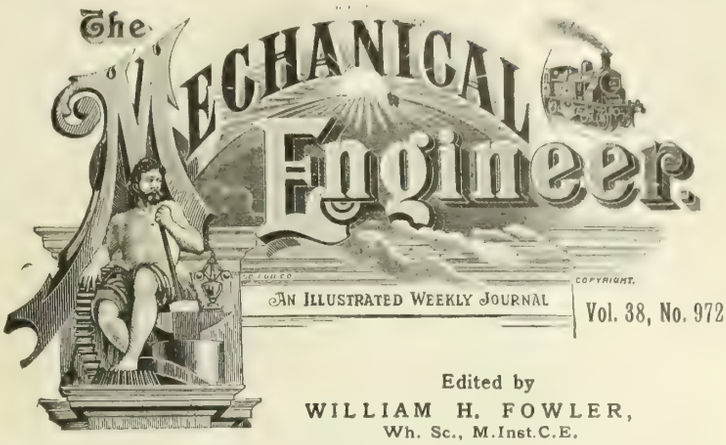

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Science and Research.

THOSE who imagined that the Research Committee of the Privy Council, appointed in July last year, would quickly remedy the defects in our industrial organisation revealed by the war will probably experience a sense of disappointment at the first annual report, issued by the Advisory Council of the Committee, though it will not surprise those who have seriously studied the matter. Our lack of scientific education and training, of which the shortcomings of many British industries are but a reflex, has been the subject of comment by these observers for years, and they know well that national ailments like personal ones cannot be cured in a hurry, and that the first step towards a cure is to clearly recognise the nature and extent of the complaint. This the Advisory Committee have done, and their report is interesting, not because it expounds a quack remedy, but because it points the need for persistent and combined effort on the part of manufacturers and scientists if a proper recovery is to be effected. It is easy to call for research, and easier still to set it going than to reap the fruits of it, but to begin with there are two serious obstacles to overcome. One is the shortage of men qualified to undertake such work; the other is the want of proper appreciation by manufacturers of its value. The average man engaged in trade, possessing often but a superficial education, and looking only to a quick ledger return as a measure of intrinsic value, promptly divides scientific research work into two parts: that which is not capable of immediate application to his business he dubs as "pure"; that which he can at once turn to profit he calls "practical." While recognising that such a division of science to industry is not difficult, and giving the application to industry precedence over "pure" science, in their deliberations the Committee point out that this discrimination is arbitrary and artificial. Rightly speaking there is but one kind of science,

viz., a knowledge of natural laws and defects, arranged, systematised, and co-ordinated. However, the Committee have to deal with the world as it is; with problems calling for immediate solution, and with manufacturers who cannot afford to wait and who are not accustomed to taking long views. "If science," said one of them to the Committee, "could enable him to overcome his daily difficulties he was prepared to welcome her, but he had no interest in research which did not produce results within a year"—presumably we suppose because he could not present them as assets in his balance-sheet. In a word, "he wanted a handy servant, not a partner with ideas of her own." It is a somewhat restricted point of view from which to take an outlook, but the Committee are limited by their environment, and they have done their best from this point of view. In the first place, they have formed a register of all research work actually being conducted at the outbreak of war in technical colleges and universities throughout the country, as well as the character and provision made in our educational institutions for such work. They have also endeavoured, as far as possible, to supplement this with information given in confidence by manufacturing firms respecting investigations they have in hand or in contemplation connected with their industries. For a complete survey it is obvious such a record is as valuable as that of the work done in teaching institutions. Hitherto much of this private work has been jealously guarded with the result that there has been much overlapping and wasted effort. It is gratifying therefore to note that in the opinion of the Council there are indications of a change of view and more far-reaching co-operation than has hitherto been possible. Manufacturers, they state, "are beginning to realise that their most dangerous enemies are not fellow countrymen, but manufacturers abroad, supported by every device, freight and tariff, and Government aid can provide." Trade associations, it is pointed out, are not as wide in this country as in Germany, and, further, have shown only a moderate appreciation of the necessity of research as a means of keeping command of markets. Several reasons are put forward to account for this comparative inactivity. Some spring from the feeling of individuality, which leads many manufacturers to hesitate in expending money on research of a comprehensive kind and the results of which may be available to outsiders. Others complain that the growth of joint stock banks handicap enterprise since they are reluctant to advance money as private banks used to do, on the character and integrity of their clients, and require easily realisable assets as security. Others, again, hold the joint stock principle of ownership responsible for works managers being often men whose training and experience is confined to their own industry, and who are apt to resist proposals for improvement. It has often been urged as a fault of the Government that it has not made grants to firms to aid research, as it has been contended is often the case in Germany. This complaint, however, would appear to be without foundation, at least, so far as direct aid is concerned, for the Committee assert they have only been able to discover one authenticated instance of a grant from public funds in Germany to an individual manufacturer for research or any allied purpose, though the German government, as already stated, frequently assist industries as a whole by tariffs, preferential railway and canal rates and harbour dues, and most important of all, by lavish expenditure on education, especially of the technical and higher commercial kind, and it is to this that the Committee mainly point as a solution of our own shortcomings. "Universities," they state, "can, and must be the main sources of research in pure science, discoveries in which lie at the root of all technical and practical applications." Summing up the conditions which appear to be necessary to success, the Committee say that these are, firstly, a largely increased supply of competent researchers; and secondly, a hearty spirit of co-operation among men of science, men of business, working men, professional and scientific societies, technical colleges, local authorities and Government departments, and that neither condition will be effective without the other. The first condition cannot be secured rapidly for the simple reason that research workers are few, and that in any case time is essential to create a supply. Scholarships may do something to attract, but in any case their training is a slow process, and it is not so much to a small brilliant group as to a well-organised army of workers that success must be looked for. The rank and file are as necessary as a general staff, and the mediocre as well as brilliant ability must be co-ordinated. The responsibility in a word for the defective position in which British industry in many directions will find itself in competition after the war must rest with the educational departments of the United Kingdom. A sufficient number of competent candidates for research work cannot be forthcoming until a larger number of well-educated students enter the universities, and to reap their efforts eventually greater co-operation in the directions indicated must be made. The particular difficulties in the day-to-day routine of manufacture, the possibility of improving processes, diminishing cost of working, enlarging output, or enhancing quality, are matters which individual firms must attack themselves, and, doubtless, will attack successfully when they realise at its proper value the application of science to their particular trade. Greater co-operative effort, however, is the mainspring from which fundamental research must emanate. It must, however, be not only co-operative, but continuous, and when finally "it is devoted to the support of national trade institutes for research, as well as to improvement of the conditions and efficiency of labour, the country will have gone far towards establishing its industrial prosperity on a firm basis." Ignorance, in a word, is the main source of the deficiencies and shortcomings in our technical industries; ignorance not so much in the lower ranks of the army of workers as amongst the staff officers, and education—above all scientific and technical education—the only effective remedy.

RESTRICTIONS ON USE OF ALUMINIUM.

THE Secretary of the Ministry of Munitions forwards the following: In pursuance of the powers conferred on him by Regulation 30a of the Defence of the Realm (Consolidation) Regulations, 1914, the Minister of Munitions hereby orders that the war material to which the Regulations apply shall include war material of the following classes and descriptions, namely, aluminium and alloys of aluminium, unwrought and partly wrought, including ingots, notched bars, slabs, billets, bars, rods, tubes, wire, strand, cable, plates, sheets, circles, strip, granulated aluminium, aluminium powder, "bronze," "flake," and "flitter." The Order, dated December 7th, 1915, published in the "London Gazette" of the same date, relating to all kinds of aluminium and alumina, is hereby cancelled. All applications for a permit in connection with the above Order should be addressed to the Director of Materials, Ministry of Munitions, Armament Buildings, Whitehall Place, S.W.

Fluxes for Brass.—According to Mr. H. L. Reason, in a paper presented before the London Association of Foremen Engineers, fluxes are not used to a very large extent in brass foundries; it all depends upon the class of metal used. For yellow brass with large percentages of scrap, ordinary common washing soda is very beneficial. For bronzes phosphorus is the best flux. In the case of castings that are difficult to make sound owing to shape or unequal thickness, a small addition of phosphorus is a decided help. It gives a homogeneous and non-porous casting. The phosphorus neutralises and deodorises the nascent oxides which are nearly always present in molten metals, increases the chemical activity, and holds the mixture in a high state of fluidity, which enables the gases to escape. Otherwise these would form bubbles in the casting. The best way to add phosphorus is in the form of phosphor copper or phosphor tin.

EFFICIENCY TESTS OF A 30,000 KW. CROSS-COMPOUND STEAM TURBINE.*

BY H. G. STOTT AND W. S. FINLAY, JUN.

THE determining factors in the selection of power generating equipment, either for an original installation or replacement purposes, present about as many variables as there are installations. Engineering experience has practically standardised the electrical end. The steam engine, on the other hand, does not seem to have been capable of such standardisation, as engineers are not agreed as to the most desirable superheat, pressure, &c., which must be considered both from the standpoint of reliability and boiler and engine economy. This thought is more than ever pertinent at this time, as it appears that we are on the eve of the employment of higher pressures and perhaps even new systems of power generation. Further, the capacity of the machine to be selected and the relation of point of best steam consumption to maximum continuous load and provision for heavy overloads for limited periods are all dependent on load factors, diversity factors, &c., which present a new problem for every installation.

Without detailing at length the considerations which led to the selection of three 30,000 kw. units for the 74th Street Station of the Interborough Rapid Transit Company, a brief summation of the main questions involved will possibly be of interest and serve to classify the installation properly. The prospective daily plant load, as was subsequently demonstrated, could be best provided for by units of 30,000 kw. maximum continuous capacity each. At that time there was assurance that machines of this capacity could be constructed and furthermore, by the employment of the two-speed compound principle, as described more fully hereinafter, no hazards were involved, nor in fact would there be any departure from well tried principles of construction. Ample steam supply was available by reason of the development in the matter of relative boiler capacity coincident with the increase in efficiency of prime movers since the original construction of the plant in 1902. Economic considerations warranted the withdrawal of the horizontal vertical double cross compound engine generator sets installed at that time, and their replacement by more efficient and larger units. The generally accepted essential requirements of a railroad plant were the next considerations, viz.: reliability, efficiency, and cost.

In the development of turbine design, at the time the installation was being considered, possibly the simplest type of machine in many ways was the single-shaft, single rotating element turbine as a natural outgrowth of the generally accepted type developed in smaller capacities. Certain structural features, however, inherent with the larger capacity tended to favour the division of the unit into two elements.

In a steam turbine, maximum centrifugal stresses are encountered at the exhaust end, where the greatest steam volume requires the greatest blade area. In the high-pressure blading which uses steam of small specific volume, the best velocity ratio conducive to high economy cannot be met by the rotative speed as determined by the exhaust end. To avoid a compromise, the conditions are more readily satisfied by carrying out the expansion in two separate elements, and avoiding congestion due to the high specific volume of the steam at one inch absolute exhaust pressure by the use of the lower speed, longer blades, and the double-flow principle. Reliability also seemed better served in the double element machine by the shorter shaft, and the reduction of danger from temperature strains. Furthermore, there was the possibility, in an emergency, of operating either element of the unit alone, and that at a fairly high efficiency, the low-pressure element being available for service simply by the use of a by-pass. The use of the high-pressure end alone in the case of a bad breakdown on the low-pressure end was to be obtained by removing the low-pressure rotor and closing the shaft openings with special covers.

An extremely important consideration, favouring the divided unit in this particular case, was the matter of the weight of the parts to be handled by the crane which, in the case of the single unit, involved provision for additional crane capacity beyond that then available at the plant. To take care of such additional requirements would have necessitated the installation not only of a new crane, but reinforcements of the steel work of a most elaborate nature and far in excess

TABLE I.—*Summary of Results. Turbine Tests.*

Test No.	Abs. Steam Pressure at Throttle		Steam Temperature at Throttle		Superheat		Abs. Steam Pressure Primary Inlet		Abs. Steam Pressure Exhaust H.P.		Abs. Steam Pressure Inlet L.P.		Exhaust Vacuum		Exh. Pres Referred to 30-In. Bar, 762 M M 58.1 Deg. Fahr., 14.5 Deg. Cent.		Load Average	Water per Hr.		Water[1] Rate		Rankine[1] Cycle Efficiency	Thermal[1] Efficiency
	Lb. per Sq. In.	Kg. per Sq. Cm.	Deg. Fahr.	Deg. Cent.	Deg. Fahr.	Deg. Cent.	Lb. per Sq. In.	Kg. per Sq. Cm.	Lb. per Sq. In.	Kg. per Sq. Cm.	Lb. per Sq. In.	Kg. per Sq. Cm.	In. Hg.	MM. Hg.	In. Hg.	MM. Hg.	Kw.	Lb.	Kg.	Lb. per Kw.-Hr.	Kg. per Kw.-Hr.	Per Cent	Per Cent
1	224 3	15.78	493.2	256.2	101.6	56.5	148	10.41	10.6	.745	10 2	717	28.411	721.63	1.589	40 37	16,342	192,350	87,250	11.770	5.339	72.540	23 72
2	223 3	15.7	486.8	252.7	95 8	53.2	144	10 12	11.8	.83	10.0	703	28.52	724.41	1.48	37.59	16,447	194,431	88,194	11.822	5.362	72.222	23.62
3	224.1	15.77	485 7	252 1	94.2	52.3	166	11.68	.	...	11 0	.773	28 539	724 9	1.461	37 1	18,158	212,029	96,176	11.677	5.297	73.118	23 91
4	223.3	15.7	489 6	254 2	98.4	54.7	159	11.18	11.8	.83	11.5	.809	28 471	723.15	1 529	38.85	18,273	212,330	96,313	11.620	5.271	73.476	24.02
5	222.6	15 65	496 5	258 05	105.7	58.7	163	11 46	11.8	.83	10.8	759	28.588	726.15	1 412	35.85	18,317	213,976	97,059	11.682	5.299	73.086	23 90
6	220.4	15.5	510.9	266 1	121.0	67 3	175	12 31	12.7	.893	12 0	.844	28.586	726.08	1.414	35.92	20,472	234,930	106,564	11.476	5.206	74 400	24 33
7	219.8	15.46	519.3	270.7	129.5	72.0	182	12.8	12 8	.9	12.5	879	28 683	728.55	1 317	33.45	21,925	250,407	113,585	11.421	5.181	74.757	24 46
8	221.8	15.6	518 8	270.5	128.0	71 1	185	13 01	13 5	.949	12.8	.9	28.791	731 3	1.209	30.7	22,150	253,388	114,937	11.439	5.189	74.630	24.41
9	221.1	15.54	501.5	260.8	111.2	61.8	187	13 15	...	...	13.0	.914	28.744	730.1	1.256	31.9	22,432	256,716	116,446	11.444	5.191	74.606	24.41
10	221.3	15.56	513.9	267 7	123.5	68 6	194	13.64	14.2	.998	14.1	.992	28.902	734 1	1.098	27.9	24,137	274,971	124,727	11.392	5.167	74.947	24.52
11	220.3	15.49	512.9	267.2	123.0	68.4	196	13.78	13.7	.963	13.6	.956	28.882	733.6	1 118	28.4	24,200	275,593	125,009	11.388	5.166	74.973	24.52
12	220.3	15.49	496 8	258.2	106.8	59.4	197	13 85	14.6	1.027	14.1	.992	28.896	734 0	1.104	28.0	25,170	285,184	129,359	11.330	5 139	75.357	24 63
13	217.9	15.32	524.3	273.5	135.2	75.2	211	14.84	14 5	1.019	14.7	1.033	28 761	730 53	1 239	31.47	26,153	295,373	133,981	11 294	5.123	75.597	24 72
14	224.0	15 76	500.0	260.	108 5	60 3	215	15.12	..	..	15.0	1 055	28 862	733 1	1 138	28.9	26,740	301,035	136,549	11 258	5.107	75.840	24 81
15	221.6	15.58	510.0	265.5	119 5	66.4	210	14.77	16.5	1.16	15.9	1.118	28 862	733 1	1.138	28.9	28,378	323,353	146,673	11.395	5.169	74.928	24.51
16	220.0	15 47	515.5	268.6	125.6	69 8	211	14 84	16.6	1.167	16.2	1.138	28.812	731.82	1.188	31 18	28,517	325,072	147,453	11.399	5.171	74.901	24 49
17	220.3	15.49	513.0	267.2	123.0	68.4	210	14.77	16.5	1 16	16.8	1.181	28 78	731.01	1.22	30 99	30,232	344,787	156,395	11.405	5 173	74.862	24.48
18	217.2	15 28	518.0	270.0	129.1	71.8	206	14.48	17.3	1.216	17.2	1 208	28.801	731.55	1.199	30.40	30,397	348,018	157,861	11.449	5 193	74.574	24.39
19	217 1	15.27	515 4	268.6	126.6	70 3	212	14 9	18.5	1.301	18.5	1.301	28.623	727 03	1.377	34.97	31,986	364,280	165,237	11.389	5.166	74 968	24.52
20	218 2	15.33	519 5	270.8	130.4	72.5	209	14 7	17 6	1 237	18.2	1.28	28.75	730 25	1.25	31 75	32,348	366,572	166,277	11.332	5.140	75.343	24.64
21	216.3	15 21	513.3	267.4	124.9	69.4	209	14.7	18.1	1.272	18.9	1.328	28.765	730.63	1.235	31.37	32,490	370,335	167,984	11.398	5.1701	74.908	24.52
22	222 8	15.66	518.0	270 2	127.0	70.5	182	12 78	13 9	.976	13.0	.913	28.55	724.70	1.45	36.83	21,610	246,661	111,850	11.414	5.179	74.733	24.42
23	224.0	15 76	508 0	264.5	116 5	64 5	186	13.05	14.2	.998	13.3	.934	28.53	724.67	1.47	37.23	21,800	250,134	113,600	11.474	5.207	74.412	24 35
24	222.9	15 67	512.0	266.7	121.0	67.3	194	13,66	14.8	1.042	13.9	.976	28.92	734.57	1.08	27.43	23,890	272,335	123,600	11.400	5 170	74.824	24.48
25	223 1	15 67	515 4	268 9	124.3	69.0	213	14.98	16.2	1.139	15.1	1.062	28.85	732.8	1.15	33 15	26,505	298,810	135,600	11.274	5 114	75.660	24.79

[1] As corrected to 215lbs. per sq. in. or 15·1 Kg. per sq. cm. abs. press.; 120° F. (66·6° C.), superheat; 29in. Hg. (736·6 mm.).

* Abstract of paper presented at the May, 1916, meeting of the New York local section of the American Society of Mechanical Engineers.

of that required for use in connection with the double unit. In the matter of efficiency the double unit offered still more desirable possibilities, prominent among which was the relative flatness of its water rate characteristic. Without entering into the matter of cost in this particular case, it may be said that the advantage was again with the double unit.

As a result of such considerations as the foregoing, the double-unit turbines were selected, together with condensing equipment designed to perform at a relatively high rate of efficiency, and including the necessary auxiliary apparatus. The high-pressure element is practically a typical single-cylinder reaction turbine, containing 38 rows of blades. The low-pressure-element is a turbine of the double-flow type. The casing is possibly unusual in its size and details of reinforcement. No blading is mounted directly in the casing, but through the intermediary of rings secured to it. The central portion of the low-pressure rotor consists of a drum to which are bolted two cast-steel shaft ends. These shaft ends have discs mounted upon them, carrying the last rows of blades. Each turbine was erected upon a foundation of steel framework set in concrete, the steel structure alone being amply sufficient for support, the concrete being added to eliminate vibration. Inasmuch as the high-pressure rotor was inherently of small diameter, it was possible to design it to operate at the maximum speed possible for 25 cycle service, *i.e.*, 1,500 revs. per minute. The low pressure turbine was designed for the next lower synchronous speed, namely, 750 revs. per minute, utilising a four-pole generator.

The surface condensers which occupy most of the open space beneath the foundation framework consist each of two shells containing 25,000 sq. ft. of condensing surface apiece. The condenser shells are connected directly to the turbine outlets without an intermediate expansion joint. The weight of the condensers is carried by means of lugs, cast as a part of the shell, resting upon a number of spring jacks, which are adjusted to carry the load without appreciable strain upon the turbine exhaust nozzles. Practically no restraint has been put upon longitudinal expansion of the low-pressure turbine by the circulating water piping, which is fitted with rubber expansion joints. There is one expansion joint of copper in the steam equalising pipe between the shells.

The condenser auxiliaries were selected and installed with the prime factor of reliability continually in mind. The turbine-driven tri-rotor circulating pumps of 37,500 galls. per minute capacity each were installed in duplicate, the reliability consideration being augmented by one of efficiency in the matter of relative requirements for winter and summer use; during the winter months with cold water one pump is sufficient, but during the summer months high water temperatures necessitating two units in service. The hot well pumps were also installed in duplicate. A single rotary dry vacuum pump was provided for each unit, with sufficient capacity to handle the dry air from two units, cross connections being provided for the purpose.

The turbines are equipped with water-sealed glands. The gland water system has a small centrifugal turbine-driven pump for each unit, the piping for all of which is cross connected through a common header. The water used for the turbine oil coolers returns the heat which is thus regained by way of the feed-water heaters.

The exhaust from the auxiliaries has been carried into the feed-water heaters, which operate at low pressure. The shortage or excess of heat in this heater system, as the case may be, is compensated for or utilised by means of heat balance valves operating between the auxiliary exhaust lines, and the receivers between the turbine elements.

For test purposes one unit was selected as representative of the installation. Tests were made upon this unit by the use of standard methods, special provisions being taken to secure accuracy, some of which are detailed below.

High steam pressures were observed by the use of gauges, in duplicate where of importance, such gauges being calibrated before and after each test. Temperatures were observed by carefully calibrated thermometers, immersed in iron pipe wells, filled with mercury or oil, depending upon conditions. Wells were of ample depth and correction was made for immersion. Low pressures were observed by the use of mercury monometers. Vacuum readings were made by the use of mercury columns provided with a vernier reading to $\frac{1}{100}$ of an inch. The mercury in these columns was regularly cleaned, and its specific gravity determined before and after test series, and corrections made accordingly. Temperature corrections on mercury columns were provided for by the use of thermometers set in each column casing and additional corrections were made for specific gravity, meniscus and barometer reading. The barometer used on the test was calibrated by reference to the U. S. Weather Bureau.

The condensate was weighed in tanks mounted upon two carefully calibrated platform scales. Platform scales were also used to measure drips and leakage. The unit was isolated so far as water and steam outlets were concerned. The large atmospheric relief valve necessarily remaining connected to the exhaust system was water sealed, the seal being kept under continual observation by means of a window in the valve cover, and interior illumination by electric light.

The unit output was obtained by means of three single-phase rotating standard watt-hour meters, one connected to each phase. These watt-hour meters were calibrated before and after the test series, which calibration included the current and potential transformers and showed no variation in excess of 0·2 per cent.

Each test was of three hours' duration with about a half hour preliminary operation under test conditions. The load was controlled from the switchboard, the turbine operating upon the governor with hand throttle wide open. This subjected the turbine to the full swings of the railroad load, as observed by means of a graphic wattmeter, which furnished an interesting index of such load variations. At light loads these variations were more pronounced, approximating frequently 5,000 kw. either side of the average. A variation of 10,000 kw. total in half a minute was not uncommon, especially on loads of 16,000, 18,000, and 20,000 kilowatts.

The results of the tests are summarised in Table I. In conducting these tests, naturally every effort was made to maintain certain standard conditions under which guarantees had been given, and the test results as tabulated have been corrected to such standards. These standards represent what is probably the average of operating service.

TABLE II.—*Condenser Test, Summary of Results.*

Pressure at throttle, absolute	220lbs. per square inch	15·466 kg. per square cm.
Temperature at throttle....	487° Fah.	252·8° C.
Superheat	97° Fah.	54° C.
Load, average kw.	31,233	
Exhaust vacuum.....	28·61in. hg.	726·69 mm. hg.
Exhaust pressure, absolute	1·39in. hg.	35·31 mm. hg.
Corresponding temperature .	89·4° Fah.	31·9° C.
Mean temperature difference (Log.)	12·9° Fah.	7·17° C.
Heat transferred per hour ..	316,000,000 B.T.U.	79,632,000 large calories.
Heat transferred per unit surface per hour	6,330 B.T.U. per sq. foot.	17,150 large calories per square metre.
Heat transferred per unit surface per hour per deg. M.T.D.	490 B.T.U. per square foot.	2,390 large calories per square metre.
Air leakage per minute	16·88 cub. ft.	478 cub. dm.
Condensate per hour	357,060lbs.	161,962 kg.
Temperature of hot-well water	86° Fah.	30° C.
Temperature of intake water	70·8°Fah.	21·5° C.
Temperature of discharge water	80·9° Fah.	27·2° C.
Rise	10·1° Fah.	5·7° C.
Circulated water per minute	64,700 galls.	243,890 litres.

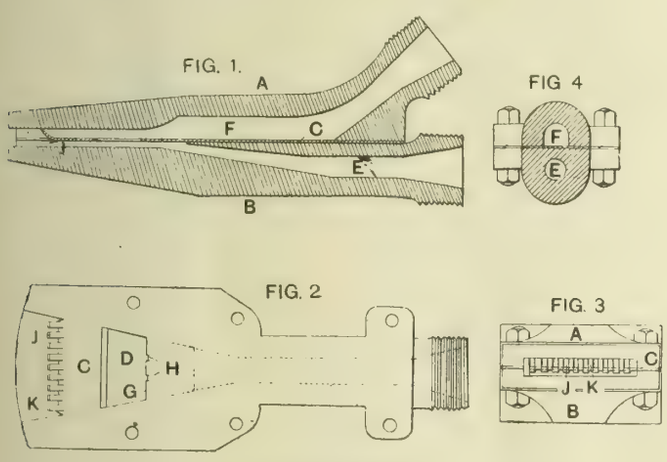
A number of tests were made upon the condensers and auxiliaries, separate and individual guarantees having been made upon the condenser proper, circulating pumps, dry vacuum pumps, and hot-well pumps. Publication of the test data upon the pumps would simply show good efficient performance without unusual features. The results of the tests upon the condenser having been given, however, simply as a matter of information and interest in connection with the installation as a whole. The guarantees were based upon operation under maximum load, viz., about 32,000 kw., and the test was made with the turbine carrying as near that load as was possible. The duration of this test was three hours, the preliminary operation under test conditions, half an hour. The results are shown in Table II. No correc-

tions were made in this test, as operating conditions approximated the guaranteed conditions very closely, with the exception that air leakage was high. The tests were made very shortly after the installation of the machine and little opportunity had been given under operating requirements properly to eliminate this leakage, which has since been done. A permanent gasometer has recently been installed in connection with each unit, in order to observe air leakage at regular intervals and aid in its elimination.

Summarising the results of these tests it may be said that the performance in the case of both turbine and condenser showed higher efficiencies than was guaranteed under contract, and the installation has proven to be thoroughly satisfactory in every particular, having fully realised the considerations which governed its selection.

LIQUID FUEL BURNER.

A NOVEL design of liquid fuel burner recently patented by Mr. C. Turconi, No. 22, Strada Dr. Kalineru, Bucarest, Rumania, is shown in the accompanying cuts. The apparatus is distinguished from other designs by the feature that the liquid fuel is mixed in a perfect manner with the supplied steam or compressed air, even when these auxiliary mediums are supplied only at a low pressure. Fig. 1 is a vertical, longitudinal section of the burner; Fig. 2 is a horizontal section; Fig. 3 is a front end elevation; and Fig. 4 is a cross-section thereof.



LIQUID FUEL BURNER.

The parts A and B are cast in one piece in gunmetal, and there is arranged between them a plate C of iron or steel, the forward end of which is cut in the form of teeth which are alternately bent up and down. The plate C is formed with an aperture D at the place where the fuel and the steam jet meet. A certain amount of steam from the steam jet in the passage E passes through the aperture D into the passage F and mingles with the fuel. Inversely, a certain amount of fuel drips from the passage F into the passage E wherein it becomes mixed with the steam. For the purpose of enabling the fuel to flow off more readily into the passage E, the edge G of the plate C is provided with two or more downwardly bent teeth H.

The consequence is that the mixing together of the two mediums takes place not only at the surface of the steam jet, but almost throughout its entire cross-section. The lower portion of the steam jet is intended to convey the fuel mixture into the interior of the hearth at the place of combustion, and therefore its initial velocity must be maintained as much as possible. A device composed of teeth J and K is provided for the purpose of effecting a complete and intimate mixture of the fuel and steam, that is to say, for the purpose of spraying the two mediums simultaneously. The two mediums already mixed together are projected by the force of the steam jet against the teeth J and K, whereby the mediums are sprayed at those points so finely that the mixture will burn with extreme ease and without the slightest trace of smoke, with the result, it is claimed, that a hitherto unattained efficiency is realised.

SOME ELECTRICAL TROUBLES AND THEIR REMEDIES.*

BY THOS. ANDERSON

FAILURES in electrical apparatus frequently require a good deal of perseverance on the part of the investigator to locate them, but an outstanding fact about them is that there is always a cause, however obscure it may be. The following are a few cases of electrical faults which have come to the writer's notice, and which at the time seemed to have perplexing features.

(1) The first occurred in a 200-yard length of three-core, paper-insulated, lead-covered, 3,000-volt cable, which ran overhead from a power house to a transmission pole, and thereafter on bare conductors to a sub-station at a mine about a mile distant. During the early part of the day, when this particular mine was going full swing, the circuit-breaker in the power-house opened. The station attendant was informed from the mine end that everything seemed all right there, and feeder switches were all open ready for the current coming on again. The power-house breaker was closed, when the same thing happened again, so it was evident that the fault was somewhere on the transmission line, and the most probable place in this three-core cable.

The cable was immediately disconnected from the line, and tested with a 1,000-volt megger for insulation between phases and between phases and ground. The insulation between phases A and B was fairly good, but between B and C the reading was zero, and insulation between all phases and ground quite good. It was therefore evident that a short existed between phases B and C. The trifurcating boxes at either end of the cable were then opened, the bitumen cleaned out, and the joints examined without any fault being discovered. Now as this cable had been in service for a few weeks only, and it was a matter of importance that the mine should be kept idle as short a time as possible, it was decided to disconnect it from the system altogether, and replace it with three separate conductors. This was promptly done, and the mine was again got under way.

The firm who supplied and erected the cable were informed as to what had happened and requested to send some one to locate the fault, but before the representatives of the firm arrived the cable was connected to a spare 400-volt generator through a three-pole switch and fuses to ascertain at what voltage the insulation would actually break down. The generator was allowed to build up very slowly till it had attained nearly 500 volts, and yet, strange to say, nothing happened. The cable was again disconnected and tested with the megger, and still showed a short-circuit between phases B and C.

Nothing more was done for a few days, when the firm's men arrived with a complete testing set. They were given all the particulars of the case, and at once set to work to locate the position of the fault. Their efforts, however, were not very successful, as from readings and calculations they reckoned there was ½ meg. of insulation across what was considered the "shorted" phase. They requested that the cable should be connected up to the 3,000-volt mains and tried. This was done and the circuit-breaker closed, and again it promptly opened. After working the better part of a day it was decided to try and burn the fault out, so that it would show itself. The cable was connected to a high-tension side of a spare transformer with a fairly heavy copper fuse in circuit. A man was posted up a pole at the far end of the cable, to watch for any smoke. The switch was closed on the transformer, the copper fuse burst, and at the same time a hole was blown through both lead and iron armour of the cable about 10ft. from the end. It was assumed that in the making of the joints in the trifurcating box moisture had got in and crept along the paper insulation to the point at which it broke down.

(2) The second case was that of a small squirrel-cage induction motor driving a water pump. This is a case of a motor running considerably below speed. For some time before the matter was reported the attendant had noticed that it took a much longer time than formerly to pump a given amount of water. An examination of the motor windings was made for bad or wrong connections, or shorted coils, but no fault was discovered there. The voltage at the motor

* Paper read before the Association of Mining Electrical Engineers (West of Scotland Branch).

terminals was tried, but that also was normal. An ammeter was put in circuit to see if overload had anything to do with it, but the current was actually less than one would have expected it to be.

The motor was then disconnected from the pump altogether, and run up alone. It came up to its normal speed quite nicely, but on taking hold of the projecting end of the rotor shaft, with both hands, it could be brought nearly to a standstill. A rotor from a similar motor was then put in and tried on load, and it ran up to and maintained its normal speed quite easily. It was therefore evident that the fault lay in the rotor circuit. The rotor bars were disconnected from the short-circuiting rings, when it was discovered that a light film of oil and dirt had collected between the bars and the rings, thus setting up a fairly high resistance in the secondary circuit, which could easily account for the reduction of speed on load. Both rings and bars were thoroughly cleaned, the rotor put in place, the motor put in service again, and no further trouble was experienced with it.

(3) The third trouble was an unbalanced current in a 3-phase mesh-connected motor. This motor was apparently operating quite satisfactorily, no trouble being experienced in the starting or running of it, but on taking current readings of each phase it was found that no two phases were taking the same current, one phase being just about right, the other two considerably higher than they ought to have been, both on no load and full load. A short time previous to this being noticed, this motor had been off for repairs, a few new stator coils having been put in. It was thought just possible that one coil of a group might have been wrongly connected in two of the phases. This was tested for by opening one leg of the mesh and sending a direct current round the stator windings and testing all round the core with a compass for correct polarity. This was found to be quite right, the compass showing N. and S. poles alternately all round the stator windings.

Since it had been proved that no open-circuits existed, the next step was to test for short-circuits between the turns of any individual coils. For this a shunt ammeter was used. A steady current of a few amperes was sent round one complete group, and the drop read off on the shunt, this being taken as a standard for all the rest. Eventually it was found that two of the groups gave a smaller deflection on the shunt than the others, and also that these two groups were in different phases. Each coil in these two groups was then tested in the same manner, and a damaged coil was found in each. In one of them the insulation was completely broken down, the turns being well burnt together, in the other quite a number of turns were found to be short-circuited. That this was the cause of the unbalanced currents was proved when, after removing the damaged coils and inserting new ones, the motor was put on load; the current readings on all three phases were practically identical.

While on the subject of unbalanced currents, the writer remembers reading an article which pointed out that circulating currents between generators in parallel may result from a variety of causes, chief among which is a tendency toward unequal generator speed, the latter resulting from slipping or bad joints in belts, difference in pulley diameters, angular variations in prime movers, or faulty engine governors. There are other less frequent causes which are sometimes difficult to discover. Quite recently there happened a case of this latter kind which is of particular interest, not only because of the unusual and perplexing cause of the trouble, but because of the liability of its happening wherever similar conditions prevail.

Two 150-kw. 2-phase alternators of the revolving-armature type were reported as indicating on the ammeters a quiet, steady current of about half-load on each machine when run in parallel without any load connected to the bus-bars, but when either machine alone was run in parallel with an incoming power line, which came in through transformers, no such effect could be seen. The trouble was said to date back but a short period to when one of the generators had a number of armature coils replaced. Subsequent to these repairs an increase of station load required the operation of both generators. The evidence of unbalanced circulating currents seemed to be very strong and convincing, and therefore an examination of the offending machine was immediately made. The armature winding was of the closed-coil type with taps brought out mechanically and electrically at points 90° apart. The winding and connections were traced out and checked several times, and proved to be absolutely correct and precisely like those of the other generator, so it was obvious that whatever was causing the trouble the repaired armature coils were surely not responsible, and therefore this clue, which at first was so promising, had to be abandoned.

Tests were made to eliminate all the usual causes of circulating current, such as slipping of belts, &c., but in these respects everything was found normal and in good condition. Voltages on the phases of both machines registered alike. Circulating current or a phantom load, such as was observed in this plant, can be produced with two alternators in parallel, when the field of one unit is under or over-excited, the proper adjustment being reached when, upon manipulating the field rheostats, without altering the bus-bar voltage, the total generator amperes are at a minimum, but here no field adjustment could be found which would reduce the apparent load. Both of the generators were of the compensator type in which an induced current proportional to that in the main leads is rectified by a commutator and circulated round the fields, the effect being similar to that of the compound winding of a direct-current machine. It was believed that there was a possible chance for trouble here, although it did not seem likely, especially at no load. However, a test was made with all the compensator circuits on both machines cut out, but this had not the slightest effect on the trouble.

The steadiness of the phantom load was such as to excite suspicion that some kind of apparatus might be connected to the generators or bus-bars unknown to the owners of the plant, and although repeated tracing out of leads and switchboard wiring revealed no such connections, in order to make doubly sure the lines of the switchboard were disconnected, and the machines paralleled through temporary wires straight from one unit to the other. After this was done an ammeter inserted in the circuit showed that the perplexing circulating current was still present. Every attempt on the part of the investigating engineer to discover a solitary symptom of disorder had failed, and as apparently all other possible tests had been made, saturation curves were taken, but these threw no new light on the question.

The capacity of the plant was so materially reduced by the circulating current that the engineer was urged to try again to locate the source of the trouble. Again taking up the thread of investigation, and reflecting that an exchange current between machines could be caused only by superimposing or combining two voltage waves of unequal value, it was evident that this was what was taking place, but from some cause as yet obscure. Means for measuring or comparing the waves of the machines were lacking; however, in the absence of an oscillograph, it was finally decided to investigate in a somewhat crude manner the main and side circuits of each alternator separately by means of an incandescent lamp which, when connected while the machine was run slowly, would keep pace with the alternations in brightening and darkening with each wave of voltage.

The alternations of the machines were readily followed, and in each case the pulsations on both phases were found to be normal. However, upon connecting to a side circuit of one of the machines, *i.e.*, to one lead from each phase, a peculiar effect was noticed. Coincident with each revolution of the armature the waves could be seen to attain a maximum and minimum, the intensity of the flashes ascending and descending with each revolution. This indicated almost as clearly as an oscillograph could have done that the electromotive force in this section of the winding rose and fell at one particular place instead of being constant as in the other machine. The reason for this irregularity could only be due to lack of uniformity in the strength of the magnetic flux around the armature.

Investigation as to the cause of the difference in field strength developed the fact that the air gap at the upper portion of the field was almost twice as great as at the lower part, and this was the cause of the rise and fall of potential in the side circuits previously mentioned. This effect, because of its being super-imposed with the voltage of the side circuits of the other machine whose potential did not vary, caused at every revolution a surging back and forward of current in the lines paralleling the machines which, however, at full speed, registered on the ammeter as a steady current.

The remedy was obvious; steps were taken to raise up the bearings in order to raise the armature to the centre of the air gap. When this work had been completed, both machines were started and paralleled. That the trouble which so long had remained a mystery had been found and removed was now apparent, for at no load the ammeters did not indicate any current. The important fact brought out by this experience was that circulating current between alternators in parallel may result from an unbalanced air gap when the machines are of the closed-coil type of winding.

(4) The next two apparently simple cases are quoted as serving to show the effect which centrifugal force may have on badly-made connections on rotating apparatus. A 500 kw. alternating-current generator had been off for some slight repairs, and was about to be put into service again. After being brought up to about its normal speed, the voltmeter plug was inserted into its receptacle, but the meter failed to give any reading. The first thought that occurred was that the plug was failing to make contact. This was examined and found to be in good order. The meter itself was then tested, but that also showed clear. The machine was then shut down and the exciter circuits tested for continuity and insulation. The armature with its field circuit was intact, as also was the revolving field circuit, the insulation also being perfect. The generator was again run up to speed, but still failed to show any evidence of excitation. In testing out the circuits for continuity, an electromotive force several times the normal electromotive force of the exciter was used, and as there was a possibility of this overcoming any weak parts in the circuits, a low-voltage incandescent lamp was inserted in series with all the respective circuits, with the result that the fault could not yet be located. There seemed little else to be tried for, unless centrifugal force was springing any of the field-coil ends enough to make them open-circuit. This ultimately proved to be the case, as after opening up a number of them, one was found on which the insulation had a charred appearance, and when opened up, the sleeve joining up the two ends of the coils was found to contain no solder whatever, and could be drawn apart with the hands. This would seem to point out that field-coil connections, when of the revolving type, should have some mechanical fixture, such as screws, in addition to the solder.

(5) The other trouble due to centrifugal force was of a similar kind. A variable-speed slip-ring haulage motor, with an eight-point controller, was reported as refusing to come up to speed on the short-circuit, and that the ammeter showed an excessive current on the last two positions of the controller. Since it was only on the last but one and last notches of the controller that the fault showed, it was obvious that the trouble lay either in the controller circuit or in the rotor windings. The controller and grids were tested through all the different points and showed all clear. The rotor circuit was likewise tested, and it also seemed to be intact. The end connections joining up the phases were then examined. These end pieces were formed of flat strips riveted and soldered on the coil ends. In one of these the rivets were found to have become loose: enough heat had been generated to melt the solder, and when the motor reached a certain speed—and that speed would be attained on the last notch but one of the controller, the two flat strips would spring apart far enough to open-circuit that point.

(6) Electrical machinery is frequently reported as failing to perform its work properly, when the real difficulty lies entirely outside the apparatus itself. One such case happened where a 2-phase induction motor was installed to operate a vertical coal elevator, replacing an old gas engine. The new motor, which was one of the latest type, looked very promising, but had hardly been started and the conveyor buckets filled with coal before it gave signs of distress, slackened its speed, and stopped. It could not be started again, and finally the purchaser, impatient at the delay, threatened immediate rejection of the motor and the installation of another prime mover. An engineer was sent for, who, on arrival, made enquiry as to the voltage and frequency of the system, but was assured positively by the superintendent of the local power plant that the voltage and frequency were unquestionably correct, and were always so maintained, but that the motor was obviously at fault in that it would not pull a load which a 5 h.p. gas engine had carried, although the motor was of twice that capacity.

An examination of the motor failed to show the slightest disorder with its windings or connections. All its circuits were clear, and, although of ample capacity, it was conceivable that in some manner the load had become too heavy. In an endeavour to diagnose the case, it was decided to make several measurements and determine the torque necessary to start the load, the available starting torque, the frequency of the circuit, and the line voltage. It is commonly thought that measurements of this kind require an array of laboratory instruments, or other special facilities; however, all the necessary data was obtained here with a spring balance, a speed indicator, and a voltmeter, and this simple outfit served to locate the trouble very rapidly.

The torque required to start the motor was obtained by attaching the spring scales to the driving belt and pulling it slowly along, thus moving the entire load, whereupon the pointer indicated a pull of 120lbs. The product of the motor speed by the circumference of pulley gave the belt speed as 1,600ft. per minute; this, multiplied by 120lbs. and divided by 33,000, gave 5·8 as the horse-power required at full speed, which proved that the motor was far from being overloaded. Next, the motor starting torque was measured at 1ft. radius. For this purpose a wooden bar was fastened across the diameter of the pulley and a notch was made in the bar exactly 1ft. from the centre of the shaft, so that the hook of the scales would remain at the stated distance. The scales were then so suspended that the projecting bar would maintain a horizontal position while resting on the hook. When current was applied to the motor, the pointer registered a pull of 41lbs., which was about one-half the normal rated starting torque for the motor. The cause of such a low torque could be either high frequency or low voltage or both, and steps were taken at once to ascertain these values. The first step in determining the frequency of a circuit by means of a motor is to know its no-load speed, when the full-load speed is given. The rated speed as given on the motor name-plate was 850 revolutions at full load, and 7,200 alternations per minute. The synchronous speed is found by dividing the rated alternations per minute by the number of poles; the next highest number above full-load speed obtainable by dividing the alternations by an even number will be the synchronous speed, while the divisor will be the number of poles. In the present case, 900 is the next highest number above 850 obtainable with 7,200, and with 8 for a divisor; hence the motor was obviously an 8-pole machine, with a no-load speed of about 900 revs. per minute or normal frequency. With the belt off the motor was given full-line voltage. The speed indicator showed 1,000 revs. per minute, which, being above synchronous speed, proved that the frequency of the circuit was high in the proportion of 1,000 to 900 or 11 per cent., and since the starting torque of an induction motor, within certain limits, varies inversely as the frequency, this was evidently one cause contributing to the weakness of the motor.

There remained only the question of line potential. A voltmeter applied to the motor terminals, with the auto-starter in running position, showed the voltage to be 154, whereas the motor was rated at 200 volts. The whole cause of the trouble was now apparent and accordingly measures were at once taken to correct the abnormal conditions. As soon as the frequency was lowered to the correct value and the voltage raised to normal, the motor started up and pulled its load in such a business-like way and with such evidence of reserve power that it thoroughly redeemed itself.

In concluding this paper, the writer will describe a method of locating faults in mining locomotive armatures, with an earthed return, which has been found simple and reliable, no other instruments other than an ammeter being required. The armature is taken apart from its field circuit (so that it cannot revolve where current is sent through it), and fixed on a cradle arrangement with the brushes in position. The controller, fields, and armature are then all wired up exactly as they would be when working with an ammeter in circuit, and about full-load current is sent round the circuit. The armature is then turned slowly round by hand. Should there be any open-circuited coils, there will be a flash at the point of open-circuit, and short-circuited coils will very soon become hot. Since one side of the system is permanently earthed, should there be any earth on any of the controller or armature wiring, these will again be flashing.

THE INSTITUTE OF METALS.

THE annual autumn meeting of the Institute of Metals will be held on Wednesday, September 20th, commencing at 4 p.m., in the rooms of the Chemical Society, Burlington House, Piccadilly, London. Sir George T. Beilby, F.R.S., LL.D., will preside, and a number of important metallurgical papers will be presented and discussed. These include: (1) "The Allotropy of Silver," by Dr. W. D. Helderman (Utrecht University, Holland); (2) Note on "Cadmium in Spelter," by W. R. Ingalls (New York, U.S.A.); (3) "The Annealing of Arsenical Brass containing 61 and 62·5 per cent. of Copper: A Study of the Structure and Properties Developed by Varying the Rate of Cooling within the Transformation Range," by C. H. Mathewson and E. M. Thalheimer (Yale University, U.S.A.); (4) "The Development of the Spelter Industry," by Ernest A. Smith, A.R.S.M. (Sheffield).

A ballot for the election of new members is being arranged in connection with the autumn meeting. Candidates for election should send in their applications before noon on September 13th, to the secretary of the institute, Mr. G. Shaw Scott, M.Sc., Caxton House, Westminster, S.W., from whom membership forms and full particulars can be obtained, post free, on application.

The Government Research Council having made a grant of £1,000 per annum towards the cost of carrying on the research inaugurated by the Institute of Metals Corrosion Committee into the causes of the corrosion of marine condenser tubes, it has been found possible by the Corrosion Research Committee, which has recently been reconstituted so as to include representatives of all bodies interested in the subject, greatly to extend their sphere of activities.

Two salaried investigators have been appointed in the persons of Captain G. D. Bengough, D.Sc., and Dr. O. F. Hudson. They will conduct scientific researches on the committee's condenser plant now about to be installed, by the courtesy of the Brighton Corporation, in the Brighton Electricity Works. The plant will be worked under ordinary industrial conditions, the microscopical and other examination of the metal treated at Brighton being carried out in the metallurgical laboratories of the Imperial College of Science and Technology, South Kensington.

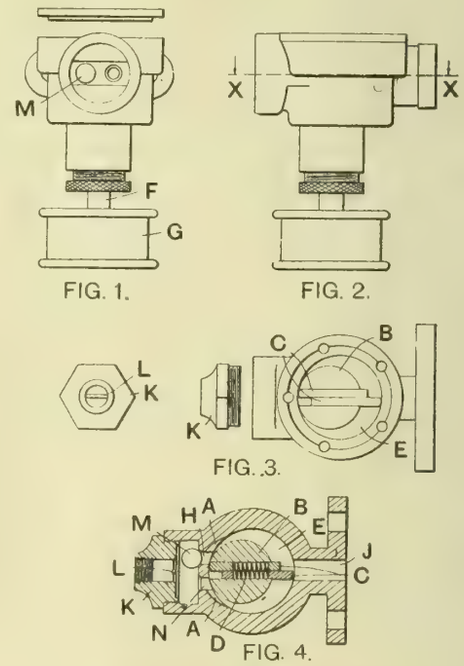
DISSOLVED ACETYLENE FOR WELDING.

DISSOLVED acetylene, or, as it is more commonly called, tank acetylene, is, says Mr. K. Dunham in the "Acetylene Journal," in wide use by all classes of users. The gas is bought, ready for use, by the opening of a valve. Care is exercised by the manufacturer of dissolved acetylene to purify it before it is compressed into the cylinder. These cylinders vary in size, according to the needs of the user, from 100 cub. ft. to 500 cub. ft. capacity. Since acetylene is dangerous under pressure in a free state, the method of eliminating this hazard is interesting. The cylinder is filled with a porous material, and then acetone, a very volatile liquid, is poured into the cylinder. This acetone absorbs the acetylene, and, as there is no free space in the tank, no danger is encountered in handling or using acetylene furnished in this way. Acetylene should not be withdrawn from the tank at a rate fast enough to bring out with it the solvent liquid, which is harmful in its effects on molten metal. The flame used should not require an acetylene consumption at a greater rate per hour than one-seventh the capacity of the tank; that is, a 100ft. cylinder should last seven hours. It is for this reason that steel welds made with acetylene from an automobile lighting cylinder are so often unsatisfactory. The gas in automobile cylinders costs more than that in the regular-size welding tanks, and, except in emergencies, the automobile cylinder should never be used. If it is necessary to employ these cylinders instead of welding cylinders it is advisable to connect three or four on a manifold to eliminate the possibility of the withdrawal of the acetone.

Lead-plated Steel.—A new process has, says "The Iron Age," been developed which will render possible the substitution of lead-plated steel for zinc and nickel-plated material, and phosphor-bronze, copper, and brass parts used where metal needs protection from corrosion caused by acids, salts, and fumes.

REVERSIBLE ROTARY PUMP.

THE accompanying illustrations show a design of rotary pump of the kind in which a rotor having one or more blades is eccentrically positioned in a casing so that the blade or blades sweep the crescent-shaped space between the periphery of the rotor and the inside of the case, the invention of the Selson Engineering Company, Ltd., 85, Queen Victoria Street, London, E.C., and Mr. Henry Goodwin. The pump is adaptable for various purposes, but is specially designed for pumping lubricants on machines which have reversible motion. The pump comprises a rotor of the kind referred to, a casing for same, one valve chamber having in addition to the outlet from the chamber only two ports or holes therein and a valve adapted to close the ports one at a time so constructed and arranged that when the rotor is rotating in one direction delivery is through one of the ports or holes and when the rotor is rotating in the reverse direction delivery is through the other port or hole. The valve in the form of a ball is automatically operated. When the pump is running in one direction the ball closes one of the outlet ports and when reversed the hydraulic pressure of the fluid immediately forces



REVERSIBLE ROTARY PUMP.

the ball from one port to the other, and thus the outflow of fluid is maintained through the port which the ball in the movement has left uncovered.

Fig. 1 is a general elevation of the pump with the pulley wheel by which it is driven; the side cheek of the case is shown removed. Fig. 2 is a similar view, but turned through an angle of 90° and with the cheek in place. Fig. 3 is a plan view as seen from the top of Fig. 1 with the side cheeks entirely removed and with the attachment for the inlet pipe, the latter being shown separately. Fig. 4 is a sectional view about the line X of Fig. 2 with the attachment shown in Fig. 3 in position. The pump comprises a casing in which is a rotor B having sliding blades C controlled by spring D. Between the rotor and the inside of the casing is a crescent-shaped space E which is swept by the blades C. The rotor has a spindle F upon which is mounted belt pulley G. The outlet or delivery side of the pump has ducts A leading to openings H, N adapted to be closed one at a time by the ball M. These openings lead from opposite ends of the chamber E, whilst the inlet port J leads into about the centre or widest part of the chamber. The outlet nozzle or attachment K is shown furnished with a bar L to prevent entry of the ball M into the bore of the pipe. When the rotor is running in clockwise direction (according to the position shown in Fig. 4) the ball covers the inlet port H as shown, but immediately the rotation is reversed the pressure of the fluid shifts the ball from the port H to port N and the supply is maintained through the port H.

INDUSTRIAL EFFICIENCY.*

BY GERALD STONEY, B.A.I. (DUB.), F.R.S., M.INST.C.E.

AT times such as these the mind naturally turns to problems to be considered both at the present time and after the war, and in considering such problems a review of some of the errors committed in the past is most necessary. Such a review enables methods which should be adopted both now and in the future to be considered. As this is an address to the engineering section of the British Association for the Advancement of Science, only such problems will be considered as affect engineering and its allied industries. One thing which has handicapped our industries is the reluctance of firms to utilise highly-educated labour or to adopt scientific methods In looking round the industries of the district one is struck by the small number of men who have undergone a thorough scientific training at one of the universities or at one of the leading technical colleges, and who occupy a prominent place in the firms in this district. The general complaint is that university and college men are too theoretical and not practical. It is the usual thing for a bad workman to blame his tools, and is it not because employers do not know how to make use of such labour that they utilise it to such a small and imperfect extent? Things are very different in some other countries with which we have competed in the past, and with which there will be in all probability still fiercer competition in the future. There we find the fullest use made of highly educated scientific labour.

How many engineering firms in this district have a skilled chemist on their staff, and what percentage of these pay him a decent salary? And how many heads of firms have sufficient chemical knowledge to appreciate the work of and utilise the services of such a man, because unless there is appreciation of the work done by such a man his services are useless and he becomes discouraged, generally finding himself up against the blank stone wall of there being no appreciation of his services; and yet chemical problems are continually cropping up in engineering work. There is the question of the supply of materials; as a rule the manufacturer trusts to the name of the contractor and assumes that he gets materials of the composition and purity he ordered. Every now and then something goes wrong and the question arises, why? Without a chemist to analyse the material it is often most difficult to say. Apart from this question of the analysis of raw or partly manufactured materials received, there is the chronic question as to mixtures of the metals in both the metal and the brass foundry, and large economies can be effected by systematic analyses.

Another direction in which scientific labour is invaluable is in seeing that instruments are in proper order and that tests are accurately carried out. Tests carried out with inaccurate instruments and without proper scientific precautions to see that they are accurate and reliable, are worse than useless, and in fact, most misleading and dangerous, as entirely unreliable inferences may be drawn from them and far-reaching troubles caused in the future. How many tests of steam engines are unreliable because there is no standardisation of the pressure and vacuum gauges and thermometers used, and how many cases is even the reading of the barometer omitted? An absolute pressure stated as so many inches of vacuum has no meaning unless the barometer reading is also given, or the inches of vacuum is stated as reduced to "Bar. 30." How many firms using steam have any arrangements for testing vacuum and pressure gauges, and yet there are no instruments more liable to error than these gauges? When one tries to analyse the results of steam tests one is constantly up against the elementary question, "Were the gauges, &c., accurate? What a misfortune it is that there were no means of testing their accuracy." Under scientific supervision arrangements are made to avoid such troubles and get reliable results which can be depended on for future designs. What has been said about pressure gauges and the measurement of pressure applies, of course, to all other instruments and measurements. In most works, it may be said with sorrow, that the only moderately accurate measurements that can be made are those of dimensions and weight. It is only by accurate testing of existing plant that reliable deductions can be drawn enabling safe progress to be made in future designs.

One of the great things which helped forward the steam turbine in the early days was accurate and full testing of each plant as soon as it was completed and before it left the works The late Mr. Willans was probably the first, or one of the first, to recognise the importance of accurate testing of steam plant, and the success his well known engine had was largely due to this. From the earliest days of the steam turbine, Sir Charles Parsons recognised the necessity of such testing, and the test house has always been a prominent feature of Heaton Works. And then in the higher ranks of an engineering works it requires a scientific mind to draw safe conclusions from tests carried out and to see in what directions progress can be safely made. Such methods have enabled the steam turbine during the writer's acquaintance with it, now extending over some 28 years, to grow from 50 h.p. to some 45,000 or more in each unit, and the steam consumption to be reduced from 40lbs. per horse-power hour to about 7½lbs. or less than one-fifth.

And closely allied to such work in engineering works is the general question of scientific research, and here a trained scientific mind is of the utmost importance to see that reliable results are obtained and to make true logical deductions from those results. Without suitable training a man is liable to be unable to grasp all the conditions of an experiment and to make deductions from the data obtained which are totally unjustified and often lead to most disastrous results in the future. Such research is generally carried out in four places —engineering works, private laboratories, engineering colleges, and national laboratories. The first has already been dealt with. The second is of comparatively small importance in practice. As regards the third a great deal of good work has been done in engineering colleges, often under great difficulties for want of plant and money, and it is greatly to the credit of our professors and others that they have succeeded in doing so much with the very inadequate appliances at their disposal, and handicapped for want of funds. How inadequate their income is can be understood when it is remembered that Leipzig University alone has an annual income from the German Government of £100,000, as against a total Government grant to all the universities here of about £45,000, or less than half.

Of national laboratories we have only one, the National Physical Laboratory of Teddington, and here again the support given to it is totally inadequate. The total income from all sources last year was only £40,000, and of this £23,000 was charges for work done, such as testing meters and other instruments, and such commercial work; the Government grant is only £7,000 a year, and besides this £7,500 was received for experiments in connection with aeronautics, which is really war work. The balance was made up of subscriptions, grants from technical societies, and miscellaneous receipts. Compare this with the German equivalent, the Reichsanstalt of Berlin, which has an income of £70,000 a year from the Government, or ten times that given to our N.P.L. The Bureau of Standards, the similar institution in U.S.A., has a Government grant of £140,000, or 20 times ours. In the Civil Service Estimates there is an allowance of £40,000 for research, an increase of £15,000 over that allotted last year. The total estimates are over £20,000,000, so that less than one-fifth per cent. is allotted to research.

It is difficult to realise what benefits might be gained by investigations which could be carried out by the N.P.L. if only sufficient funds were available, and of what importance they might be to industry at large. One example may suffice. Some time ago the Reichsanstalt carried out a most complete set of tests on a certain class of machine, an investigation which must have cost several thousands of pounds sterling, apart from the time it occupied. The results of this investigation are available to German manufacturers of this machine, and just before the war preparations were being made to take advantage of this, and from figures stated a large extra economy was expected. This, of course, would enable them, provided the cost of manufacture was not too high, to have an enormous advantage over such machines manufactured without this special knowledge. The Institution of Mechanical Engineers saw the importance of this problem and appointed a Research Committee to deal with the question, but the first question met with is that of finance. Should this be the case in a wealthy country such as this that depends on its manufactures for its very existence? And that such an investigation is

* Address of the President of the engineering section of the British Association for the Advancement of Science, delivered at Newcastle-on-Tyne, September, 1916.

obvious from the fact that the designs of no two independent manufacturers of this machine in this country agree among themselves. Of course, each claims his is the best, but this cannot be so.

Investigations in engineering shops do not meet such a case. The question of finance has to be carefully watched, and as soon as results sufficiently good are obtained they are generally accepted, and in any case the problem is rarely thrashed out to the bottom, an almost universal defect in commercial research work. Without the help of the National Physical Laboratory the position of the aeroplane in this country would be very different from what it is, and what has been done for the aeroplane requires to be done in many other directions.

But what firm here would do what has been done in the commercial synthesis of indigo, on which it is said that 17 years' work and over £1,000,000 has been spent by one firm alone abroad. Here in chemical investigations and manufactures the Government refuse to even give the help of allowing cheap alcohol to be obtainable, and much of such work is impossible in this country on this account, as in many cases methylated and denatured alcohol are not suitable. Recently under pressure the restrictions have been somewhat relaxed by the Government, but many manufacturers have found that the privileges granted are so tied up in red tape that the concessions are practically useless.

And it is not only on the scientific side that there is so much to be done in the way of putting our house in order; there is much to be done in the way of putting the management and commercial sides of engineering and other allied works in a position to compete. The great growth of engineering works and their being formed into limited liability companies has not been without its drawbacks. In the old days an engineering works was comparatively small and, as a rule, one man, generally a clever engineer, was at the head. After his death, and often before, the place was turned into a limited liability company, and gradually fell into the hands of a body of men, many of them not technical, who had no further interest in the firm than to draw their salaries as directors and managers, and who had no financial stake in the concern beyond the £500 or £1,000 in shares necessary to qualify them as directors. The result is that the place gradually degenerates, initiative ceases, and it finally gets to a stage of not paying any dividends, and really being kept going, not for the sake of the shareholders, but of the directors and other officials.

Such a firm as a rule does not put enough aside for depreciation, and thus its machinery and buildings degenerate and become obsolete, which makes it still less able to compete with more modern firms. At the same time it is not able to afford the money necessary to carry on the experimental and research work which is a necessity for any progressive firm, and thus its manufacturers cease to progress with the times. As Sir Charles Parsons truly said, a man or firm in the face of financial difficulties cannot carry on research work, and, further, that the minimum spent on research work should be at least 1 per cent. of the turnover, and that the amount it is advisable to spend is 3 per cent. Unless a firm makes good profits it cannot keep up to date, and will sooner or later go to the wall.

But the workman says that he should have his share. What is his share under the present state of things? The average capital expended in an engineering works per individual employed is about £200. An investigation the writer made some years ago gave this figure, and it was confirmed by an investigation of shipbuilding yards, which gave £185, and of the Census of Production, which gives a capital of £1,500,000,000 for 7,000,000 workers, or £214 per man. An investigation of the dividends paid shows them to be about 4 per cent. on the capital employed. Here it must be remembered that firms paying 10 to 15 per cent. on their ordinary capital have often a large preference and debenture capital, on which a much lower rate of interest is paid, and also that often part of the ordinary capital was issued at a premium. Also account has to be taken of the large number of companies that do not pay any dividend on their ordinary stock, and often none on their preference. Little is as a rule heard of the finances of such companies; it is the ones paying good dividends that public attention is drawn to. It thus means that the shareholders get about £8 per year per individual employed.

On the other hand, the average wages for men and boys, skilled and unskilled, is about £70 per annum in normal times. This means that the worker gets between eight and nine times as much as the capitalist, and shows on what a very small margin the capitalist works. And without the capitalist, under our present system of individualism, there would be no factories erected and run, and therefore no work for the working man, a thing it is well for him to remember, and also that without profits the capitalist will not invest in engineering and other works in this country, but will seek for a more profitable field for his capital elsewhere. Every £200 invested in this country in a factory means work and livelihood for one British working man.

At the same time I am sorry to say the employer does not look after the welfare of his workmen as he might. In a small factory the head of the firm, as a rule, knows all the leading men among the workmen, many of them having been with him for years. As the place grows he loses touch with his men, and as an actual fact knows fewer of those under him when he has 1,000 or more employés than he did when he had 400 or under. This state of things gets worse when the place is turned into a limited liability company, as nearly all large places are at present. The result is that a most deplorable state of things has come to pass. The workman says, 'Put not thy trust in employers'; the master says, 'Put not thy trust in workmen'; and the official who is between the master and the workman says, 'Put not thy trust in either.'

It is difficult to say what is to be done to remedy this state of things, but one cannot help feeling much might have been done in the past to have prevented such a regrettable state of affairs as there is at present. Much of this trouble might have been avoided if employers had shown more consideration for the welfare of their workmen. Of course, there are some notable exceptions, but they are few and far between. An example is the necessity of the Factory Acts to ensure proper light and air and other arrangements necessary for the health of the workmen. But much more should be done. Why is it that canteens are being rushed up all over the country, and why were there so few before? In many works to this day the provisions for getting food and drink warmed are most primitive and inefficient, and as to getting anything to eat if one has to work overtime unexpectedly, it is in most works impossible. As a rule the only thing available was a drink at the public-house outside the gates, and even this is now closed at five o'clock. Why if a man works overtime should he also starve? And how can efficient work be expected under such conditions? Why also should there not be provision for drying clothes after walking to work on a wet morning, and each man be provided with a cupboard where he could keep a change of boots? Why are not sanitary arrangements decently private, and why are they not kept clean and wholesome: they are often in a disgraceful state? These are only a few samples of the directions in which much might be done.

The adjustment of the wages to be paid to the workman is a most difficult one. There are three principal ways of paying workmen—on time, on piece, and on bonus. On time is the only way of paying a man who is on various classes of work, where the fair time required for each job is not known, and in many cases the most highly skilled men are on such work, and as a result only make time wages. This results often in the highly skilled man making less money than the less skilled man who is on repetition work and as a consequence is working on piece or bonus, and this is obviously unfair. For example, a man may have the setting up and adjusting of a number of machines on repetition work, and he often makes less money than the less skilled men under him who are on piece or bonus, although their nominal rate of wages is less than his. Again, highly skilled erectors who go outside the works to erect machinery, often worth thousands of pounds, and set it to work, are only paid on time, and often make less money than their fellows who are on piece inside the works.

The adjusting of piece prices is a most difficult one. They should be adjusted so as to be fair both to master and man, but too often such fixing of prices is left to subordinate officials who have in many cases their own axe to grind. There should in every works be a special department for such fixing

of prices, and once a price is fixed it should not be altered without good reason. The practice of cutting prices by the masters in the past is, in the opinion of the writer, largely responsible for the present limitation of output by the men about which we hear so much. There is a rule that if a man makes more than time and half or time and third the price of the job is to be cut. If the price has been fairly fixed why should it be reduced because the man makes large wages due to his skill and industry? The larger the output from his vice or lathe the better for the master, as he is getting a larger output from his plant with a certain capital expenditure, and thereby establishment charges are reduced. This is especially the case in machine work, as the hourly value of the machine employed often far exceeds the wages of the workman employed.

A fair rating for machine tools is 4d. per hour per £100 value, and as the time rating of the man is generally about 9d., it is easily seen that if the average value of the machine tools exceed £225, machine charges exceed time wages, and the average value of machine tools is generally largely in excess of this figure, in fact often about double it. It is therefore obvious that it is much more important to get large output than to pay small wages. The result of this "time-and-half" rule is that a good man by working up to the limit of his capacity "spoils the job" for the next man who comes along and may not be of the same calibre as the first man. It has therefore been found advisable and necessary by the workmen to limit the output of all men to a certain standard, and this results in the end by the pace being set by the slowest man on a particular job. A fair bonus system is perhaps the ideal way of paying men, but here, again, although the times for a job are supposed to be fixed and unalterable, in too many cases they have been altered by various devices, and as a result the system is looked on with suspicion by the workman.

Gradually bit by bit the pernicious doctrine that the less work done by a man the more employment there will be has grown up, he not seeing that the cheaper an article can be produced the larger will be the sale for it and the better it will be able to compete with the products, not only of other producers in this country but of those abroad. And also that very cheapness, combined with good quality, induces the sale for such articles to be large. Laziness is inherent in man, and on an average no man will work unless compelled to do so, and still less will work his best unless there is a great inducement. This is true not only of the working man but of all other classes. Therefore the policy of "Ca' Canny" has been only too readily adopted on the ground not only that it was pleasant for the man himself but also he believed that it tended to the welfare of his fellow-workmen.

The writer has very reluctantly come to the conclusion that the workman of to-day is not doing as much work as was done some 30 years ago when he was in the shops, and not only this, but that timekeeping is not as good. In this connection, however, it must be remembered that excessive overtime inevitably leads to bad timekeeping. Bad timekeeping causes much more loss than that due to the actual time lost, as not only does machinery and other plant lie idle, but the disorganisation caused in a works by lost time is most serious.

With the growth in strength of the trades unions, which at first were for the legitimate object of seeing that the workman got fair play, and providing out-of-work and old-age benefits, &c., has grown up a system of trades union officials who live by agitation, and whose job would be gone if there were no supposed grievances to agitate about. These men keep the labour world in a constant state of agitation, and make the employers' and officials' existence a burden to them by constant demands of all sorts, many of them utterly impracticable and unfair. When they cannot agitate against the employer they agitate against another trades union, and thus endless disputes spring up on the demarcation of work. Some of the worst strikes in the past have been due to disputes between two trades unions.

Unless something can be done to bring master and man together and make both work for the common good, English trade must inevitably go down, and the supremacy that England has in the engineering of the world will come to an end. Nothing ever was a truer statement than that recently made by Lord Joicey that this country, unless it produces as cheap or cheaper than other countries, cannot in the long run keep her trade, and this is true in spite of any tariff walls which may be set up. And if the present state of affairs is maintained of unscientific management and obsolete machinery, combined with limitation of output and high wages, or, in other words, high cost of production, we must, sooner or later, go to the wall. What is really wanted is common honesty and common sense on both sides, for one side is as bad as the other at present.

And now about the official, who is in all grades from the manager down to the foreman, and who comes between the master and the man. Unless he is treated fairly by the master, and unless he treats his men fairly, there is sure to be friction and loss of efficiency. He must also work with his fellow-officials who move in lines more or less parallel to his, and here, to prevent jealousies and to prevent the more unscrupulous among them taking unfair advantages, demarcation of each official's duties and work is most important. This is a point often omitted to be taken sufficiently into account in the organisation of a works, and often causes most disastrous results. The duties of each man should be clearly defined by the master, and no interference with those of others tolerated. The master also should remember that the official has no trades union or similar organisation to protect him, and should act accordingly. Much more could be said about the relations of the official both with his fellow-official who is on the same level as himself, with his master who is above him, and the workman who is under him, but time forbids. On all three sides much improvement could be effected. The fact remains, however, that for success it is essential that all from the apprentice to the head of the firm should work as one homogeneous whole.

Apart from the considerations set out above, combinations among the firms employed in any one trade are most essential for the well-being of that trade. It is by such combination that much of the progress made of late years by our competitors has been effected. Some of these combinations have been international, and at least two such in the engineering trade before the war were so. These now, of course, are, and it is expected will be after the war, confined to the allied and possibly to neutral countries, but such combinations, whether among all the engineering firms in one district or among firms employed in one particular trade, to be successful must be worked fairly to all members, and the larger firms must not override the smaller, as, it is regrettable to say, has been done in combinations of employers in some districts. For example, in a district where there is one firm very much larger than any of the others, it is not unknown for it to act the bully and insist on everything being done as would suit its requirements, regardless of the rights of others. And further, such combinations are, unless directed by men with broad minds and able to take a wide view of things, liable, especially in case of emergency, to do much harm.

If the armament ring in this country had taken such a view when it was found what an enormous supply of munitions was required, it is doubtful if there would have been such a shortage as there has been. Hundreds of firms were willing and anxious to help in the production of munitions, but when they offered their services they were met in many cases with a blank refusal, and in all cases with little encouragement. And when, under pressure from the Government, the ring accepted outside help, in many cases the conditions imposed on the subcontractors were unfair in the extreme, apparently the whole idea of the ring being to make all the profit they could out of the troubles of the Empire. It has been just as difficult to persuade the armament ring to give up what they thought was their monopoly and to bring in outside works to help in the production of munitions as it has been to persuade the trades unions to forego trade customs and to enable outside sources of labour to be employed, such as women and other unskilled labour. But both have had to do it. In other words, "dilution of works" has been as difficult to effect as "dilution of labour," and the position of both the armament ring and of the workman would have been very different if they had consented freely to it when it became obviously necessary for the safety of the Empire.

Combination among workmen is admittedly a necessity if they are to have fair play, but combination among employers has come later and is equally a necessity. At present most of the principal federations of employers deal only with wages

questions and questions affecting labour, but they require to be extended so as to take in all branches of the business of engineering. Labour has long seen the importance of federation, it is now for capital to do the same. One of the great difficulties has been that certain firms would not join, and a very small proportion acting thus weakens the whole to a much greater extent than the actual ratio of this small proportion of the whole. It is easy to see how alive labour is to this by the constant trouble over the non-union question, and this is well put in the notice addressed last March to the transport workers of the Mersey district, "To be outside a union is to be disloyal not only to your own class but to yourselves individually." What applies to labour also applies to firms, for a firm to be outside the federation is to be disloyal, not only to its fellow-firms but to itself. Such a state of affairs is not tolerated in some of the countries competing with us, and it is questionable whether action by the Government is not advisable.

An example of the mischief done by a few who would not fall into line with the many is seen by the necessity for the Act compelling the early closing of shops one day a week. The great majority were ready to close, but the action of a small minority prevented their doing so, and in the end compulsion had to be used on the minority. Legislation has not been necessary to prevent "blacklegging" in the labour world since other methods have been used which have been practically successful, but it is quite possible it may be necessary to use compulsion to make firms toe the line.

Such combinations are not only for labour questions but also for all other subjects affecting the engineering industry at large, and more especially the special industries in which any one firm deals. Thus they resolve themselves into general federations of all engineering industries and minor ones dealing with particular trades. The former deal chiefly with labour questions and questions affecting the industry as a whole, the latter with those affecting any particular trade. Among the questions coming up to be considered by the latter class is the standardisation of specifications and conditions of contracts as well as in some cases the adjusting of prices to avoid unfair competition and to put the whole trade on a paying basis. Much has been done in this direction with most advantageous results in certain cases, but much more remains to be done if this country is going to hold its place in the world.

The necessities of research work have already been dealt with, and by the pooling of such research work enormous advantages in any one trade could be obtained. Such pooling of information has been effected with most beneficial results, especially in the chemical trade abroad. Any workable scheme which would enable this to be done and get over the jealousies between one firm and another would be of enormous benefit to the trade in general. Another thing that must not be lost sight of is the urgent need of improving our educational system. It is little short of a disgrace that the older universities are closed to those without a knowledge of Latin and Greek. Languages are of the greatest importance to an engineer, but not dead languages but live ones. And these should be properly taught, so that the student should not only be able to read and write them but also to speak and understand them. It is quite a different knowledge of a language to be able to read, write, speak, or understand it. Many people can read a language without being able to write, speak, or understand it, and conversely it is not uncommon to meet people who can speak and understand a language without being able to any large extent to read or write it. And it is only in live languages that a man is trained to speak and understand a language.

Why is it that we are so wedded to the dead languages? There is, of course, the tradition that such are necessary for a liberal education, and there is the argument that modern languages are not as good a training for the mind. Granted that they are not quite so good from the point of view of learning to read and write them, does not the fact that they can also be taught as a live language to be spoken and understood make them on the whole the best educationally for a man? This is entirely apart from the fact that modern languages are useful and ancient useless to the man in commercial work. There is, of course, bitter opposition from that most conservative man, the schoolmaster, and one great reason is that it is much easier and cheaper to get a man to teach Latin and Greek than modern languages which have to be taught orally. The teaching of Latin and Greek as it is usually taught has been standardised to the last degree, and as a result they can be taught by the "semi-skilled" man, and a "skilled" man is not necessary, to use engineers' phraseology. In fact, teaching of Latin and Greek is a pure "repetition job." At the same time no education is complete unless science is combined with languages and also literature, and here lies one great danger of modern technical education.

And after the boy has left school and enters the shops more facilities should be given to enable him to not only keep up but continue his education. In the shops and drawing office too often the boy is left to pick up a knowledge of his trade as best he can. The apprentice who asks questions is often looked on as a nuisance, and requests for information are generally met by a blank refusal or worse. Often the foreman or chief draughtsman is afraid to answer questions for fear of being charged with giving away so-called "trade secrets," but an immense deal of information can be given to an apprentice without doing so. Evening classes are all very good in their way, but more facilities should be given for the diligent apprentice to attend day classes, and this can be arranged in various ways if the employer has a will to do it. A thing that at present often prevents boys desirous of educating themselves getting on is the fact that overtime is allowed as soon as a boy is 18, and often he is compelled to work overtime regardless of classes that he ought to be attending. It is important to remember that the boy of to-day is the man of to-morrow.

One complaint is that after a lot of trouble is taken about a boy he leaves after a few years and goes to another employer. The good of the trade in general must be considered, and a man who has had experience of various classes of work is generally a much more valuable man than one whose knowledge is confined to one class only. In any case the other employer gets the benefit of what has been done by the first, and thus the trade in general benefits. It is felt that this is a very imperfect review of things as they are at present, but if this address induces all classes engaged in engineering to consider how things can be bettered the author feels that a part, at all events, of his object has been attained.

HIGH TEMPERATURE INSULATION.*

BY P. A. BOECK.

THE value and importance of efficient insulation for the prevention of thermal losses are shown in the extent of the investigation and research which have been devoted to that factor in the conservation of heat, but it was not until the comparatively recent introduction of the heat balance-sheet that the various causes of heat losses and the reasons for their existence were brought to light.

Heat is a form of energy consisting of molecular vibrations of a periodic character and subject to the general laws of wave motion. It can be reflected, refracted, and dispersed by creating the proper conditions. In other words, by the proper mechanical manipulation we can increase or decrease, within certain limits, the amount or rate of heat flow. One of the most common ways of doing this is by introducing alternate layers of materials having different heat-transmitting values, thus breaking up or changing the wave length. The introduction of air cells or voids within the body is a most effective method of accomplishing the reduction of the conductivity, though large voids have the effect of propagating heat by convection and radiation. The density of a body may be taken as an approximate criterion of its heat conducting capacity.

Conduction is the action taking place in the transfer of heat in which the heat energy is passed along from a particle at a higher temperature to one at a lower temperature by virtue of their contact. While this method of heat transfer applies to the three states of matter, it is of magnitude only in solids.

Radiation.—By radition heat is transferred from one body to another without any material agency by wave motion; this applies only to the gaseous state of matter.

Convection is that process of heat transfer in which some

* Abstract of paper presented at the Chicago local section of the American Society of Mechanical Engineers.

portion of the body whose temperature is raised moves to another place in the medium where the temperature is lower, tending to raise the temperature of the medium. This method of heat transfer is therefore limited to liquids and gases.

Applying these methods to a steam boiler, the heat generated by the fuel burning in the firebox is imparted to the dry surface of the boiler plate by radiation from the hot fuel bed, furnace walls, and luminous flames, and secondly, from the moving gaseous products of combustion by convection. From the dry surface it travels through the soot, metal, and scale to the wet surface purely by conduction and is in turn transmitted into the boiler water mainly by convection.

That portion of the heat which is transferred to the walls of the furnace setting by any of the three methods mentioned is conducted through the setting and lost by radiation or convection from the outer surface of the setting, if means are not provided to prevent it. It is the heat lost in this manner and methods for its prevention that will be especially considered.

The amount of heat conducted through a unit area from one part of the body to another is proportional to the difference in temperature of the two parts; directly proportional to the thermal conductivity of the body through which the heat passes and inversely proportional to the distance between the two parts of the body. In other words, the conduction of heat through a solid body from one place to another is a direct function of the conductivity of the body and the difference in temperature of the two planes, and an indirect function of their distances apart. This is identical with Ohm's law for transfer of electrical energy.

The heat transferred from one body to another by radiation is proportional to the difference of the fourth powers of the absolute temperatures of the two bodies. While this is strictly true only of the ideal "black-bodies," the variation is so small that, for all practical purposes, this relation holds good in ordinary procedure.

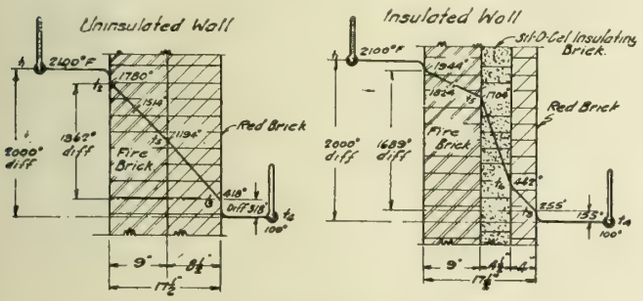


FIG. 1.—HEAT FLOW AND TEMPERATURE GRADIENT THROUGH HEATED WALLS.

This relation indicates why a hollow-wall space is an effective insulator in low-temperature work, such as refrigeration, &c., whereas in high-temperature operations the loss of heat by radiation through a hollow-wall space is so great that its insulating effect is less than if this wall space were filled with material of rather high thermal conductivity. This is especially true if the air space in the hollow wall is near the furnace side and becomes highly heated. This is entirely contradictory of the general belief that, since air is a poor conductor of heat, air spaces built into the walls of a furnace will greatly reduce heat loss by radiation. While the heat does travel very slowly through the air by conduction, it leaps over the air space readily by radiation, because the quantity of heat which passes across the hollow space is a function of the fourth power of the absolute temperature of the surfaces enclosing it, which loss is enormously increased by rise in temperature.

In general, in high-temperature furnace construction, there are two separate and distinct factors which must be considered to produce an effective wall. The first of these is to provide a material having the ability to resist the action of high temperatures, sufficient mechanical strength and, possibly, the property of resisting corrosive slags, gases, &c., without spalling or being eroded. The second is to prevent the excessive loss of heat due to conduction from the interior of the furnace to the outside where it is lost by radiation or conduction.

It is rare that a good refractory material is an insulator, usually it is necessary to augment or back up the refractory with some material having a much lower heat conducting capacity. Fig. 1 is a graphic presentation of heat transfers with and without such application. The quantity of heat H in B.T.U. per hour per square foot conducted between two surfaces of a wall is

$$H = \frac{1}{\frac{d}{c} + \frac{d_1}{c_1} + \frac{d_2}{c_2} + \cdots} \times (t_2 - t_3)$$

where d, d_1, d_2 = thickness in inches of component layers of wall, c, c_1, c_2 = thermal conductivities in B.T.U. per square foot per inch thickness per hour per 1° difference in temperature at the average temperature of the component layers of wall, and t_2 and t_3 = surface temperatures of the respective sides of the wall in degrees Fah. Fig. 1 is a graphic presentation of the heat loss through insulated and uninsulated walls; respectively 289 B.T.U. and 639 B.T.U. per square foot per hour.

The requirements of the insulating backing for the more refractory linings of furnaces are rather severe, and although an enumeration of them would seem a somewhat formidable array, there are products upon the market which fulfil practically all of them. When the kind of refractory material that is best suited to the surface has been determined, the next most important item is the thickness of the walls and the nature of the insulating material most suitable, and it is necessary to determine the degree of insulation which will produce the most effective results.

In attempting to obtain perfect insulation, it is entirely possible to over-insulate, causing a serious damage to the refractories in the high temperature zones of the furnace. To maintain the inner walls, it may be necessary to permit a considerable flow of heat through the wall, with a corresponding decrease in the temperature of the refractories at the heated point, in order to prevent their destruction. However, the issue in some instances may be met by other practical methods, such as increasing the working capacity of the unit in order to make use of the additional heat available, rather than to let this valuable heat at the critical period escape to save the refractory lining—a method which makes the working load control the temperature. In electric-furnace practice, where extremely high temperatures are encountered and where effective insulation is necessary because of the relatively high cost of current, the question of insulation or rather over-insulation, has been given more attention than in other lines.

The requirements of an ideal insulator being known, it remains only to select such an insulator as apparently most nearly meets these requirements. A material possessing remarkable non-conducting properties is "Celite," so-called on account of its extremely cellular nature. It is a mineral of a highly siliceous composition and of very light weight, and occurs on the Pacific Coast in an exceptionally pure state. It is composed of numerous hollow cells, and weighs in its natural rock form, air-dried, from 25lbs. to 30lbs. per cubic foot. When this material is ground properly, it weighs but 8lbs. to the cubic foot, and has a thermal insulating power of about 9 to 12 times the insulating power of ordinary firebrick. In other words, a 1in. layer of this material is the equivalent in insulating value of from 9in. to 12in. of firebrick. Being almost pure silica, its melting point is high, 2,930° Fah. (1,610° C.) as reported by the United States Bureau of Standards, and it can be subjected to high temperatures without fear of alteration.

Bricks and blocks of various sizes and shapes are prepared by sawing the natural material by means of gang saws. Standard 9in. straight "Sil-o-cel" brick made from natural celite weigh from 1½lbs. to 2lbs. each, and are equivalent in insulating value to many times their thickness of ordinary firebrick. In crushing strength these bricks withstand over 400lbs. per square inch and are sufficiently strong to stand transportation and handling. The cost of these insulating bricks is but little more than that of firebrick, and that of the powder about one-third as much. Because of the variation in forms in which Sil-o-cel products are supplied—that of brick, blocks of various shapes, in powdered form, and as a plastic cement—this material is adaptable to almost any form of thermal insulation.

DIESEL ENGINES versus STEAM TURBINES FOR MINE POWER PLANTS.

In a paper by Herbert Hass, presented before the American Institute of Mining Engineers, a chart, reproduced herewith, is given, which shows whether it will be more economical to install the steam turbine or the Diesel engine under given conditions of coal and oil costs. Although the paper is based on conditions at mine power plants, much of it is applicable to general power conditions.

The author states that about 12 times as much water will be required for condensing with the steam turbine as will be needed for jacket cooling of 2-stroke-cycle Diesel engines and 20 times as much water for 4-stroke-cycle Diesel engines. Another condition favouring the use of Diesel engines is the high load factor at which most mine power plants operate.

The author compares the cost of the power with, on one hand, four 3,000 b.h.p. Sulzer Diesel engines direct-connected to alternators and exciters, and, on the other hand, with two 6,000 kw. steam turbines. The results the author finds are that, with outputs of 70,000,000, 52,500,000, 35,000,000, and

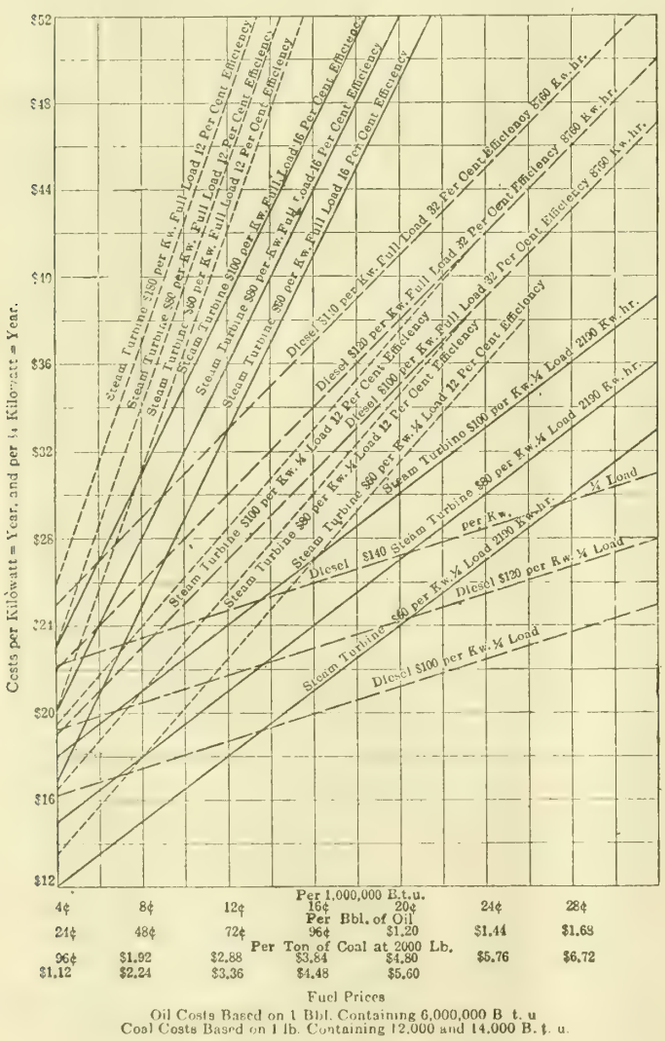


DIAGRAM SHOWING COMPARATIVE COSTS OF STEAM TURBINE AND DIESEL ENGINE PLANTS AT GIVEN FUEL PRICE AND LOAD FACTOR.

17,500,000 kilowatt-hours per year, respectively, a kilowatt-hour will cost from 1·0257 for the highest output to 1·6291 cents for the lowest output with steam turbines, and from 0·6045 to 1·0856 cents with Diesel engines.

The general selection of either type of prime mover will be governed by the following economical considerations:

(1) Where the cost of a given number of B.T.U. is high, due to high fuel cost, and the load factor also is high, conditions favour the use of the Diesel engine.

(2) Lower B.T.U. price and low load factor conditions favour the steam turbine due to the influence of interest and amortisation costs. This applies particularly to stationary power plants, which are operated only occasionally or have supply recurring peak loads.

(3) Conditions demanding readiness for constant and instant service favour the use of the Diesel engine. Against the difference of the interest charges of the Diesel engine and the steam turbine would have to be balanced the cost of keeping the boilers under steam continuously.

(4) If the power plant is located at the sources of fuel, either in the oil fields or at coal mines, the steam turbine will be favoured as costing less to install, and therefore fuel expenditures will be of less moment than interest and amortisation charges.

(5) Combination plants using the Diesel engine for supplying continuously and nearly constant main loads and steam turbines for furnishing periodically recurring peaks by the use of high duty boilers with large water and steam space and capable of forcing will prove profitable. Thus, such periodical peaks as are produced in hoisting may be taken care of by a turbine floating on the line and operating in parallel with the Diesel engine.

(6) Where waste heat gases are available, steam power will prove the cheapest.

(7) Up to capacities of 1,000 h.p., steam turbines can compete with Diesel engines only in special cases, such as supplying exhaust steam for heating purposes. For such small units, particularly for varying loads, high-grade reciprocating steam engines are preferred. Plants between 1,000 kw. and 10,000 kw. require careful analysis to determine the relative advantages of the Diesel engine and the turbine. In these analyses load factor, fuel price, and water conditions must be considered. For power plants of larger than 10,000 kw., using units from 6,000 kw. upward, it is preferable to use steam turbines unless a combination of high load factor, high fuel cost, and poor water conditions favour a Diesel plant.

In comparing prices of different kinds of fuel, such as gas, coal, or liquid fuel, it is well to reduce all fuel prices to a common basis of absolute cost for 1,000,000 B.T.U. This, together with the knowledge of the thermal efficiencies of different prime movers, will enable one to arrive at the absolute fuel cost of each per brake horse-power-hour with different kinds of fuel. When a supply of liquid fuel is available, the sound economic application of steam turbines and Diesel engines is determined by fuel prices and load factor. The diagram shows at a glance whether a steam turbine or a Diesel engine power plant is in place with the given fuel price and load factor. The power costs represented by the curves include capacity costs and fuel costs but not operating labour. The latter is about the same for either type of plant, except for very large steam turbine plants, which require less operating labour than Diesel engines. The curves marked *quarter load* cover fuel costs for ¼ kilowatt-year, or 2,190 kilowatt-hours, and the same capacity charges as for full load; to arrive at the cost per kilowatt-year (8,760 kilowatt hour) at quarter load, the amount shown in dollars must be multiplied by four.

The curves for steam-turbine plants are based on 12 and 16 per cent. efficiency (overall of the entire power plant); the higher figure is secured only with large units in sizes from 10,000 kw. upward.

The cost for lubrication is considerably higher for Diesel plants than for turbine plants, and amounts to from $2.00 to $4.00 per kilowatt-year, depending on the type of lubricating system used and the care of oilers. In turbine plants this greater expense for Diesel engines is partly balanced by the large amount of water required for condensing, which is 12 to 20 times greater than the supply needed for cooling Diesel engines.

The Institution of Mining Engineers.—The 27th annual general meeting of this Institution will take place on the 14th and 15th inst., at the Royal Technical College, George Street, Glasgow. The following papers will be read, or taken as read: (1) "The Permeability of Coal to Air or Gas, and the Solubilities of Different Gases in Coal," by J. Ivon Graham. (2) "The Formation of Water in the Oxidation of Coal," by J. Ivon Graham. (3) "The Form and Structure of the Coalfields of Scotland," by David Ferguson.

CENTRAL STATION PROTECTIVE FEATURES.*

BY N. L. POLLARD AND J. T. LAWSON.

THE entire territory served by the Public Service Electric Company comprises three principal divisions the Northern, Central, and Southern which include the more densely populated sections of the State of New Jersey. The Northern Division consists of eight generating stations having a combined capacity of 148,000 kw. and feeding 33 sub-stations. The Central Division consists of five generating stations having a combined capacity of 17,800 kw. and feeding 13 sub-stations. The Southern Division consists of four generating stations having a combined capacity of 32,000 kw. and feeding 17 sub-stations.

In the larger stations current is generated at 13,200 volts 3-phase, both 25 and 60 cycles, and in most cases is distributed at that voltage between the various stations and sub-stations, through 260 miles of underground cable and 425 miles of overhead lines. In the smaller stations current is generated at 2,400 volts 2-phase 60 cycles and distributed locally at that voltage. That part of the current not consumed locally is stepped up to 13,200 volts 3-phase by means of Scott-connected transformers. In certain sections the loads have increased so rapidly that it has been found necessary to change some of the transmission lines to 26,400 volts, and to install step-up and step-down transformers with a ratio of two to one. The method of operation is to run all stations in multiple, which necessarily means that the largest and most economical stations deliver the most output. The older and smaller stations are used at peak periods and as stand-by stations.

Six years ago, in the Northern Division, there were too many cable failures in relation to the mileage. The total number of line and cable interruptions since 1913 has decreased, while the mileage has increased. This was brought about by eliminating as rapidly as possible all equipment that was proved defective and by the use of such safety devices and connection schemes as are described later. While the installation of aluminium arresters has made the apparatus trouble disappear almost completely and the failures of cables have decreased, it has, as might be expected, not given all the desired protection to the cables. The reason for this is probably due to the fact that the surges on the cables are in the form of distributed charges and the potentials rise locally in the cables entirely beyond the protective influence of the arrester.

Upon analysing these cable failures it was noticed that the majority of them were caused by faults to ground which later developed into short-circuits. At this time due consideration was given to the question of grounding the neutral of the system, but after taking all the factors of the problem into account, including continuity of service, &c., the idea of grounding the neutral was abandoned and it was decided that, as far as the system was concerned, the best remedy was the arcing-ground suppressor. An arcing-ground suppressor was installed in the largest generating station and numerous aluminium-cell arresters on different parts of the system, in the belief that they would be the remedy best adapted to meet the requirements. The arcing-ground suppressor has been in service about five years, and the records show that it has operated in every case where a fault to ground occurred, by extinguishing the arc and preventing an interruption to service. In addition to preventing service interruption caused by single-phase grounds, it has the great additional advantage of protecting life. There are at least six cases on record where actual contact with the 13,200-volt wires was made by the workmen, which did not result fatally. There is no question but that each of these cases would have been fatal if the suppressor had not been in use. This conclusion is based on experience with the rest of the system not equipped with a ground suppressor and also on the system before the suppressor was installed.

The arcing-ground suppressor consists of three single-pole independent motor-operated oil switches, electrically and mechanically interlocked, to prevent more than one operating at the same time. Each switch is connected to ground on one side and to the bus on the other. The suppressor is controlled by a balanced 3-phase potential relay, which remains inactive while the system is balanced, but when unbalanced, due to a ground on one phase, it operates the corresponding phase of the suppressor, which in turn grounds the same phase of the bus; thus shunting the current and extinguishing the arc. In cases of short circuit, an extra precaution is taken to prevent possible operation of the suppressor by the addition of an overload relay which opens the control circuit of the suppressor.

Working in conjunction with the suppressor is a device known as the faulty cable localiser, which serves the purpose of indicating the particular feeder on which an arc to ground occurs. This device consists of a relay connected in series with the neutral of the feeder-current transformers. When a ground occurs, the secondary current of the transformers becomes unbalanced and causes the relay to operate. This in turn rings a bell and lights a pilot lamp which indicates the faulty feeder. It takes about 0·15 of a second for the localiser and 0·3 of a second for the suppressor to operate. There is one record of a 15-minute interruption to the service in the Northern Division caused by a cable end bell short-circuiting on an armature lead of a generator in one of the stations, before the suppressor and localiser were put in service; the same thing occurred again and the situation was handled in such a manner that no one outside of the power station was the wiser. A number of instances are on record where a ground has occurred on sub-station busses without an interruption to service.

As a further means of reducing cable troubles to a minimum a careful investigation was made of the possible causes of failure. A thorough study was made as to the best method of making cable joints and particular attention was given to such factors as (1) favourable weather conditions, (2) elimination of impurities, air, and moisture, (3) application of insulating varnish between each layer of tape, (4) careful and even winding of tape, (5) improving the human element. Aside from installation precautions, we have made it a practice to inspect cable during the process of manufacture and to see that the cable specifications are strictly adhered to. All cables are tested with 26,000 volts for three minutes before putting them in service, but we do not make a practice of testing them periodically. In case there are indications of trouble on a cable while in operation, it is cut out of service, given a test of 26,000 volts for three minutes, and returned to service in case no failure occurs. In our opinion a 13,200-volt cable should not be tested at a voltage higher than 26,000, since our experience has shown that too high a testing voltage often weakens the insulation at some point, which weakness finally manifests itself in a complete breakdown, even under normal operating voltage.

Our line insulators used a number of years ago consisted of many different types, no one type having been standardised. The old insulators not only spilled over during trouble, but also frequently became punctured. The insulator-creepage surface was then increased, and the insulators tested with high-potential 60-cycle current, but without satisfactory results. About two years ago we started testing with high-frequency and were soon convinced from the results obtained that the insulators were not capable of standing this test. Various types of insulators were then experimented upon and a design finally adopted having ratio of puncture to flashover of about 2 to 1. Now, every insulator before being placed in stock or used on the lines is given a 15-second high-frequency test. Although these insulators are previously tested at 60 cycles, about 2 per cent. fail to pass the high-frequency test.

At the present time, generators of such large capacity are being used that it is necessary to protect them from the effects of disastrous short-circuits by means of internal or external reactance. Where several generators are operated in parallel, it is essential that bus-tie or bus-section reactors be used in order to prevent the combined capacity of all the generators from feeding into any one point of short-circuit. Bus-section reactors will limit the current on any one section, but take up valuable space in the bus, complicate the connections, and in cases where parallel feeders are connected to different sections of the bus, it is difficult to obtain balanced currents in these feeders. The use of tie-bus reactors has none of the disadvantages of the bus-section reactors and does limit the amount of short-circuit current on any one section to any value desired, depending upon the amount of reactance used.

It is obvious that practically all interruptions in a trans-

* Abstract of paper read before the American Institute of Electrical Engineers June 28th, 1916.

mission system will be minimised if faults are easily and quickly removed before they have had time to cause serious trouble. In order to determine the proper setting of instantaneous overload, inverse time-limit and inverse definite time-limit relays which are more commonly used on a system of distribution, it is necessary to know the characteristics of the system as well as the characteristics of the generators, automatic apparatus, circuit-breakers, regulators, &c., before anything can be done along these lines, and before the time elements of relays can be adjusted, the following information is necessary: (1) The instantaneous short-circuit value of current through each conductor to which the relays may be applied. (2) The sustained short-circuit value of current through each conductor. (3) The time in changing from 1 to 2. (4) The time required for various automatic circuit breakers to open the circuit after application of current through the trip coils. (5) The safe current-opening characteristics of various circuit breakers. (6) The time characteristics of the various relays. (7) The probability and amount of flow of energy in the case of circuits operating in parallel.

Assuming for the moment that the seven items listed are known and an attempt is made to accurately time relays for selective action, the accuracy of current values required to trip a relay can be left as a matter of small concern, for when a short-circuit occurs, the current setting of relays is usually exceeded by at least several hundred per cent. This applies equally well to inverse time or definite time relays. It is an impossibility to get selective setting with the inverse time-limit relay because it has the unfortunate characteristic of being instantaneous with a heavy overload. This characteristic prevents the use of this type of relay for selective action, because a short-circuit of sufficient magnitude will cause all the relays from the fault to the source of supply to become instantaneous, and thus any or all of the relays are liable to trip out instead of only the ones nearest the fault.

Better results can be obtained by the use of an inverse definite time-limit relay, the time setting of which depends upon the damping action of a permanent magnet on an aluminium disc, giving as great a degree of accuracy as can be obtained in the calibration of watt-hour meters used in connection with a torque compensator. This type of relay is more accurate and allows closer setting than any other type, and when once set, remains the same, but in an extensive system the results obtained from its use are nevertheless disappointing. The reason for this is simple, when it is considered that the time interval between successive circuit breakers should be equal to the time taken for the circuit breaker to open its arc, plus a margin of safety to include variation, and if there are several feeder sections in series and the trouble should be near the generating end, the short-circuit may not be cleared for several seconds, which means, of course, a loss of all synchronous load on the system, or, in other words, a complete interruption to the service.

From the foregoing it can be seen that, irrespective of the character of the distribution system, it is practically impossible to isolate faulty cables or lines by the relays most commonly used, and therefore the records of most operating companies show that faulty feeders usually interrupt a large area and a great many more consumers than is necessary. With the relays more commonly used, the most satisfactory results are obtained by using them with a radial distribution system; or, in other words, most operating companies get the best results by adapting their systems to meet the faults in the relay rather than design a relay for a minimum cable outlay.

In connection with the seven tie feeders between City Dock and Marion so much trouble was experienced owing to the lack of a selective action of the relays, that a new type of relay known as the "balanced selective relay" was finally installed at each end of these feeders. The relay coils are connected in series with current transformers of the tie lines. This causes the current in each coil to be proportional to the current in the cable to which it is connected. Only a single phase of each cable is taken care of by a single relay, and there are as many coils on the relay as there are cables. For instance, with seven cables on a 3-phase system there are three relays with seven coils per relay. Each coil on each relay is mechanically balanced against each other coil. The effect of this is that any strong coil can overcome any weak coil. In case a short-circuit occurs on one cable, the current in the faulty cable will of course be greater than the current in any other cable. Therefore, the coil connected to the current transformer on the faulty cable will have the strongest pull and will close the tripping circuit of this oil switch.

However, if none of the parallel cables are short-circuited, but trouble occurs on some radial cable, the relay will remain balanced and none of the good cables will be erroneously tripped out. The relays operate simultaneously at both ends of a faulty cable, and their operation is not affected by fluctuation in voltage due to trouble or change of phase angle between voltage and current. With this particular type of relay it is necessary to have not less than three feeders in service, in order to secure perfect operation under all conditions. It should be further borne in mind that reactance coils are installed on both ends of the tie feeders in order to secure the best selective action of the relays. It is questionable whether the relays would operate as satisfactorily in all cases without the aid of these coils. The successful operation of these relays is limited to three or more feeders, therefore they cannot be used on other parts of our system where there are but two parallel cables between stations.

Since the installation of the balanced selective relays we have had no case of cable failure on the tie feeders where the relays have not operated properly, and there have been more than 50 cases of trouble. Our operating conditions are such that at times there are but two tie feeders in service, therefore on these occasions it is necessary to disconnect the balanced selective relays and depend on overload protection. Judging from past experience with different types of relays, a pilot-wire relay would seem to be the best one to adopt if it were not for the trouble and expense entailed by the necessity of the pilot wires. Therefore some scheme based on the pilot-wire principle, having all the advantages and none of its disadvantages, would be an ideal one for our interconnected system. Our investigation shows that the nearest substitute for the pilot-wire scheme and one that has practically all the advantages is the split-conductor principle. During the coming year we expect to make several installations of this character.

The multi-recorder is a device for recording the time to the fraction of a second of the sequence of action of oil switches, circuit breakers, potential-indicating devices, and aluminium cell arresters. A record of this kind is invaluable to the station man in analysing troubles or ordinary switching changes. In order to have complete information on the performance of station apparatus under all conditions, it is highly desirable to have records of the closing and opening of circuit breakers, operation of lightning arresters, appearance and duration of high voltage in the lines, and the occurrence of grounds and short-circuits.

The insulation-resistance recorder is an instrument that gives a daily graphic record of the insulation resistance of the system. The results obtained so far from the use of this instrument have been rather disappointing, owing to the fact that there are so many old insulators of different insulation characteristics. When the insulators are all changed so that they will have the same characteristics throughout the system, we can, by establishing a point on the chart which might be called "dangerous," but which is well above the breakdown point, give the operator an opportunity to report when the insulation of the system reaches this value. By isolating the transmission circuits one at a time, the line in question can be removed from the system and later, by high-potential testing or other methods, the bad insulators can be located and removed from the line. In using this instrument on lines where the insulators have been standardised, very good results have been obtained. Its use has also shown the need of increasing the insulating qualities of porcelain, which is something that we did not know before.

For several years it was our practice to install resistance bulbs in the windings of the largest turbo-generators and synchronous motor-generator sets, in order to know at all times the temperature of these machines. The results obtained by their use so far have not met with expectations. The resistance bulbs furnished to-day are somewhat more substantial than the earlier type, but are still too frail to stand much hard usage. In the windings of our more recent motor-generator sets thermocouples have been installed which we believe will give better service than resistance bulbs, as they are less liable to mechanical injury. The temperature

indicator has been found very useful in determining when a machine needs a thorough cleaning. Thus a possible burnout is prevented which otherwise could not be foretold. It is our opinion that wherever possible thermocouples should be installed at the hottest points in the windings of all large generators or motors.

In most of our stations where air-blast transformers are installed, a common air chamber is utilised for all the transformers, and we have found this method of air supply more economical than to use a separate and independent blower for each transformer. Each transformer is equipped with a top and bottom air damper, so that in case of fire in the transformer the dampers may be closed, thus shutting off the air supply and smothering the fire. We strongly recommend top and bottom dampers on all air-blast transformers, especially where a common air chamber is used If the transformers are not equipped with both top and bottom dampers and a fire starts in one of the transformers, it is necessary to cut off the entire air supply for a considerable time, depending upon how long it takes to put out the fire. This might compel the station man to disconnect the other transformers from the service, thus resulting in a complete interruption.

The coherer alarm device is used to register predetermined voltage rises on the transmission line itself, across reactance coils or on aluminium-cell lightning arresters. In order to get a permanent record of its action, it can be connected to a relay which will make a record on a multi-recorder. This device has been found very convenient to register the discharges of our aluminium-cell lightning arresters. Previous to the installation of this device it had been the custom to install with each aluminium-cell arrester a discharge recorder which has a continuously-moving paper punctured by the discharges. We finally came to the conclusion that while these recorders gave us much desired information, the continual replacement of paper record rolls was expensive and troublesome.

Electrostatic potential-indicating devices are used to indicate potential on feeder circuits. The instrument is connected to the middle point of two strain insulators in series, which are connected between each live wire and the ground. The displacement current through the insulators is sufficient to operate the instrument. Another method of obtaining the voltage indications is to install potential transformers whose secondaries are connected to indicating lamps or voltmeters. However, this means is rather expensive and the required space for potential transformers is not always available. It would therefore seem that the potential-indicating device now on the market might fill a long-left want.

COST ACCOUNTING FOR MANUFACTURERS.*

IT is a fact too little realised that an accurate determination of costs is fundamentally related to manufacturing efficiency. More and more concerns are joining the ranks of those who realise the necessity of knowing accurately their costs of manufacturing and selling. Every business man who joins in this work can feel that he is doing his part toward the improvement of business conditions generally and his own business conditions in particular. This bulletin has been prepared with a view to aiding the campaign of education by explaining what a cost system is, how it operates, the results obtained, and the benefits to be derived from its operation.

There are a number of objections in the minds of business men who have not installed cost systems to taking the matter up. One of these is the feeling that exists in the minds of so many that their business is unique and different from any other and that no system could be devised which would give them true costs. It is unquestionably true that some lines of manufacture lend themselves more readily to the installation of a cost system than others, but it is also true that no line of manufacture is so complicated that a system cannot be devised which will give reasonably accurate results.

The most common objection is that of the cost of installation and the expense of operation. Many manufacturers are of the opinion that a cost system means an interminable amount of detail and red tape and the assistance of a number of extra clerks. It is true, in many cases, that some extra labour may be required, but not to the extent that the manufacturer fears. There is in nearly every office that is not systematised sufficient unnecessary work done to cut the extra work down to a minimum, and, in fact, in some cases, where an office has been systematised, it has not been necessary to employ any extra help at all. If the manufacturer will look upon a cost system as an investment which he expects to produce for him a fair return in the same manner that an investment in improved machinery would, the objection as to the expense is not a valid one. A number of business men think that money spent for stationery is wasted and that a cheap ready-made book will answer as well as one specially designed for his business. Other business men are of the opinion that they do not need a cost system because they know what their goods cost. They may, and a number of them do have an approximate idea of what their goods cost, but in a large number of instances this supposed knowledge is based on foremen's guesses in advance as to the time necessary to do the work or as to the time spent on the work after it is done. Guesswork is unsafe and poor business practice.

Formerly the necessity for the determination of true manufacturing costs was not as imperative as it is to-day. Margins between cost and selling price in most lines were larger. Costs could be ignored except in a general way and a good return still be made on the investment; but to-day margins of profit in most lines of trade are very much narrower than formerly, and the necessity for the most efficient management and closest analysis is felt as never before. It is necessary to-day for the business man's success that he know on what articles he is making a profit and on what he is incurring a loss. Competitive conditions are seriously disturbed where losses on one or more articles are recovered by profits on other articles. It is obvious that a manufacturer should not only know the cost of each article he manufactures, but that he should see that every article manufactured bears its proper share of factory and general overhead. Most manufacturing plants have grown to a size which renders personal supervision impossible. The only reliable way, therefore, by which an executive can judge of the efficiency of an organisation is through a system of periodical statistical reports. These reports can only be accurately obtained when a good cost system is in operation.

New methods are being introduced and improved machinery installed in the factory every day, with a view of reducing costs either by the elimination of waste or by increasing efficiency. It is impossible to know whether the introduction of these improvements will reduce costs unless the manufacturer knows not only what his total cost is but exactly what items make up the total. Items of cost are frequently lost track of when the total only is considered, while if these items were properly segregated so as to show what they were they could be materially reduced and in some instances eliminated altogether.

In the past many manufacturers disliked to give out information concerning their business. To-day the reverse is the case. Trade associations are compiling statistics as to production, shipments, and costs for the benefit of their members, and the manufacturer instead of trying to keep this information to himself welcomes the opportunity to supply the data, knowing that his competitors are doing the same thing and that these statistics will be of benefit to himself and to his industry. The Federal Trade Commission is keenly alive to the value of this information. The commission is urging manufacturers to determine their costs accurately in the interest of better trade conditions. It believes that anything that is of benefit to an industry is of benefit to the public, and it is also of the opinion that the nearer cost systems approach uniformity the more valuable will be the results.

A large proportion of manufacturers are not making the money they should. A great number of them are actually losing money. The purpose of conducting a business is to make money, and the only way to make money is to sell something for more than it costs. The first essential, then, is to know the cost. It is the belief of the commission that the small margin of profit existing in so many of our industries is due to the ignorance on the part of manufacturers of what their goods actually cost to produce. This ignorance causes them to make unprofitable prices, which the manufacturer who does know his cost is forced to meet to a large extent. The prime object of a cost system is to determine costs, to analyse and compare them, and to use them as a basis for making prices. But the uses and advantages go further. A

* From a pamphlet issued by the Federal Trade Commission, Washington, D.C.

manufacturer from reliable records is able to make clearer and more intelligent statements to his bank and thereby obtain a larger line of credit than he could without them.

In most every line of manufacture there are some classes of work done on which the manufacturer loses money. This may be due to the high cost in his own plant, or it may be due to the fact that some competitor is better equipped to make that particular article. A cost system will bring out these facts and will show the manufacturer which lines he should push. Salesmen, like everyone else, are prone to follow the line of least resistance. In salesmanship, the line of least resistance is selling the goods which require the least effort, and in nearly every instance the goods which require the least effort to sell are the least profitable lines. If the selling force know that a line of goods produces little or no profit and are told to use every effort to push another line, the result will be apparent in the profit and loss account. Still other manufacturers have customers on their books to whom they have been selling for years and have been giving some reduction in price or some concession in the way of extra work. A number of these accounts are decidedly unprofitable, and a cost system will bring these to light and put the manufacturer either in a position to raise his prices to a profitable basis or let some one else have the unprofitable business.

In every manufacturing business there are bound to occur leaks, either of material, labour, or expense. If statistics are kept showing the amount of material necessary to do certain classes of work, the amount of labour, and the amount of overhead expense, an increase in any of these items will be revealed by a comparison and the executive will be in a position to take the matter up for investigation. It is hardly necessary to say that after a few of these matters have been taken up with the factory the factory people will use a little more care, not only in the use of the material but in the time they spend on the work. A cost system with forms properly designed for giving statistical information is of the greatest aid to factory efficiency.

A system will not run itself; neither will it in itself reduce costs nor increase efficiency. This is strictly up to the manufacturer himself. A system will give him the information, and if this information is properly used, he will unquestionably find that his system is not an item of expense, but a very valuable asset. If a manufacturer purchases a new machine before his old one is worn out, he does so because he expects the amount expended to increase his profits either from economy in operation or from an increase in production. He looks on this as an investment and not an expense. Office methods have been improved to quite as large an extent as machinery, and an investment in improved methods will produce a return just as will an investment in improved machinery.

One of the strongest arguments in favour of installing a practical cost system is the fact that every manufacturer who has installed one and who has operated it for at least a year is firmly convinced that it is a paying proposition. The Commission is urging manufacturers to give the subject of accurate costs the attention it deserves. It has found that unreliable costs of production and distribution cause a great deal of unfair competition and a heavy business death rate. While the claim is not made that a cost system will save a man from failure, the claim is made that a man who knows where he stands day by day is very much less likely to make a failure of his business than one who is directing his business by guesswork.

The Performance of Flexible Staybolts.—A committee of the Master Boiler Makers' Association, in a report presented at the recent annual convention, furnished data as to the number and behaviour of flexible staybolts in use on the various railroads in the United States. The data refers to 17,026 locomotives owned by 56 railroads, and the average per railroad is as follows: Total number of engines equipped with flexible staybolts, 309; total number of engines with full installation of flexible bolts, 22·4; total number of bolts in service, 174,713; total number of flexible bolts found broken in full installation in past six years, 39; largest number of flexible bolts found broken at time of inspection in any class of power, 5; average cost of flexible bolt test per engine, $28.42; per cent. of flexible staybolts removed on account of breakages or defects, 0·343 per cent.

CRYSTALLISATION IN COLD-WORKED STEEL.*

BY RALPH H. SHERRY.

AN article of interest to manufacturers using various forms of cold-worked, low-carbon steel was published in the "Bulletin" of the Society of Automobile Engineers for May, 1916. The author has investigated the occurrence of coarse crystallisation or grain growth in low-carbon steel with a number of commercial materials, particularly hot-rolled rod, cold-drawn wire, hot and cold-rolled sheet, cold-rolled strip, cold-drawn tubing, and pressings. In the manufacture and use of these materials mysterious epidemics of breakage have appeared from time to time, often only aggravated by the use of treatments supposed to put the steel in the best possible condition. Material supposed to be of fine grain would frequently break with a coarsely crystalline fracture.

Recent investigations, of which a brief survey is given, have thrown considerable light upon this phenomenon, and methods of prevention and cure for many materials have been determined. According to the author, "the formation of coarse grains in low-carbon steel will follow the action of a limited amount of strain exceeding the elastic limit and subsequent annealing within certain temperature ranges. This has been confirmed by all investigators."

In the writer's investigations it was noted on varying by narrow steps the amount of strain within the range mentioned that the less the applied strain the greater was the grain size on subsequent annealing. Within the limiting range of strain and near the lower limit there seems to be a definite or "critical" strain below which the range of temperature within which grain growth occurs is limited by the Ar_1, Ar_2 thermal critical points (about 690° and 780° C.—1,275° and 1,435° Fah.). When the material is strained beyond this point, the annealing range is considerably extended, falling between about 650° and 900° C. (1,200° and 1,650° Fah.). The moderate grain growth occurring below 650° C. (1,200° Fah.) noted by other investigators was not found in the author's investigation. This "critical" strain mentioned above has not been noted by other investigators, but the quantitative effect of strain on the grain size has been partly confirmed by the work of Chappell.

The experimental operations were carried on by forging, cold-drawing, cold-rolling, and cold-pressing, *i.e.*, stamping. The reduction of area, with its origin at the elastic limit, was selected as the standard of measurement in the quantitative determinations on account of its convenience and ready application. Some coarse crystallisation was produced in hot-rolled rod by hammering cold and subsequently annealing within the temperature ranges mentioned. None was noted in hot-rolled rod or annealing after the rolling operations.

Samples of hot-rolled rod of from ¼in. to ⅜in. diam. were drawn to various sizes and samples from each draft annealed at temperatures between 650° and 900° C. (1,200° and 1,650° Fah.). No grain growth was found outside of this range. In a number of tests the amount of reduction was varied by as narrow steps as possible, in some cases 0·001in. These samples were annealed at various temperatures within the range mentioned. It was found that within certain limits the grain size after annealing is inversely proportionate to the applied strain, decreasing gradually with increasing strain until the normal size is reached, with reductions of area of about 25 to 30 per cent.

In these experiments it was noted that with reductions of about 9 per cent. or less, the temperature range within which grain growth occurs on annealing lies between about 690° and 780° C. (1,275° and 1,435° Fah.), annealing above the higher temperature completely refining the grain. The only exception noted was in cases where the action of the strain was irregularly distributed. On the other hand, when the reduction of area is greater than about 9 per cent., the range of temperature within which grain growth occurs on annealing falls between about 650° and 900° C. (1,200° and 1,650° Fah.). There is apparently a "critical" strain occurring at about 9 per cent. reduction of area. Little or no effect was produced by reductions of area below about 8 per cent.

These results were checked by a number of similar experiments. Some difficulty was encountered in duplicating the

* Abstract of paper read before the American Society of Automobile Engineers, June 12-16th, 1916.

results, especially with the lowest reductions, owing to slight variations in the diameter of the rod or to its being slightly out of round, the effect at times being confined to the periphery or to local areas. Somewhat similar results were obtained with cold-rolled strip.

The same conditions were found to occur in certain cold-pressing operations. In pressings of the cup type the greatest amount of strain occurs at the periphery of the blank, reaching a minimum at the bottom of the pressing. On annealing typical pressings within the temperature ranges mentioned, grain growth was found to occur, of greatest extent near the bottom where the strain was the least, and decreasing gradually toward the top, where the maximum strain was applied. The same "critical" strain noted in the cold drawing was found in these pressing operations.

The presence of coarse crystallisation has considerable effect upon the physical properties. The resistance to shock and the tensile properties are noticeably affected. In tests made it was found that the elastic limit, maximum strength, and elongation are all lowered.

The occurrence of coarse crystallisation in commercial materials such as sheet and strip steel, tube, cold-drawn rivet steel, and cold pressings will next be considered. In hot-rolled sheet no grain growth was found in sizes heavier than 0·130in., but was common in all thinner sheet down to 0·065in., the lightest size examined. The grain growth was generally moderate, usually being between 0·08 mm. and 0·12 mm. diam. In some cases grains as large as 0·40 mm. diam. were noted, usually in the heavier sizes. Where grain growth was found in cold-rolled annealed sheet it was generally coarser than that found in the hot-rolled. Sheet of decided coarse grain may give serious trouble in certain operations such as pressing. When it is necessary to refine such material annealing above 790° C. (1,450° Fah.), or in some cases above 900° C. (1,650° Fah.), is necessary.

On a commercial scale the detection of grain growth is rather difficult when applied to sheet, requiring the combination of a microscopic examination and a tensile test.

The prevention of grain growth in hot-rolled sheet requires the control of a number of factors rather difficult to regulate. To ensure its absolute elimination, annealing above 900° C. (1,650° Fah.) is required. The difficulty of annealing sheet at this high temperature is obvious, although box annealing should be feasible. Somewhat the same conditions apply to cold-rolled sheet, where control of the reduction of area, a decidedly difficult factor to control, is necessary.

Grain growth may readily occur after certain cold pressing operations. Where 0·20 carbon steel can be used, no grain growth will occur, but in the usual practice low-carbon steel is used in which grain growth can readily be produced. Where the pressing operations are light improper annealing will cause grain growth, and control of the annealing temperature is of the utmost importance in such cases. The annealing of pressings is usually looked upon as an operation requiring only elementary control, the main consideration being that the metal reach a temperature high enough to soften it. The usual tendency is to keep the temperature up and so it may frequently rise within the dangerous range.

The selection of the proper annealing temperature depends to some extent upon the nature of the operation and the condition of the metal. Certain upsetting operations require annealing at temperatures slightly above 690° C. (1,275° Fah.) and a few pressing operations are of this nature. In such cases or where a decidedly coarse-grained structure exists in the metal, annealing it at about 790-800° C. (1,450-1,470° Fah.) may refine it sufficiently; if not, 900° C. (1,650° Fah.) will be required. Temperatures between 600° and 650° C. (1,110° and 1,200° Fah.) are usually sufficiently high to remove the effect of cold work. In the case of pressings, annealing just below 690° C. (1,275° Fah.) will usually produce grain growth so slight that it will not be the cause of any trouble in further operations.

Grain growth can only occur when the strain applied has been comparatively light, and control of this factor, as for instance by the increase in the extent or number of the operations before annealing, will generally permit the use of any normal annealing temperature. Very often, however, the effect of the operation cannot be foretold and some variation from normal may occur resulting in a comparatively light strain in some unexpected place.

Grain growth, usually of a moderate size, generally occurs on the edges of annealed blanks, following the action of the blanking press. Where further work is applied to the blank before annealing, grain growth does not usually occur. This same condition may occur around punched holes. Grain growth will occur following certain light bending operations if the annealing temperature is not properly controlled.

General methods of prevention and cure are as follows. The control of the annealing temperature as mentioned is of primary importance. Where grain growth has occurred and refining becomes necessary, heating above 900° C. (1,650° Fah.) will refine the grain completely. If the scale produced should be troublesome, the material may be quenched in water, subsequently annealing at 540° to 675° C. (1,000° to 1,250° Fah.) if necessary. A little concentrated hydrochloric acid thrown into the furnace at the start will loosen the scale so that it can be readily removed. In many cases annealing at 790° C. (1,435° Fah.) will refine the grain sufficiently to prevent further trouble. To summarise, grain growth in low-carbon steel can be avoided by the use of comparatively heavy operations on the metal before annealing, or by proper selection and control of the annealing temperature according to the working conditions. If the material is not annealed, no grain growth can occur.

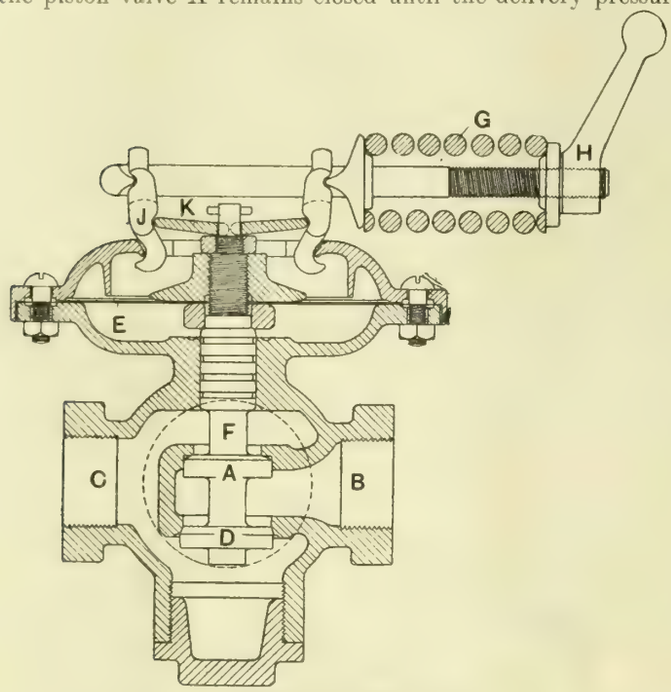
Conclusions.—(1) Grain growth in low-carbon steel may be produced by permanent deformation within certain limits, followed by annealing within certain temperature ranges. (2) The greater the amount of strain applied within these deformation limits, the smaller will be the grain size produced by annealing. (3) The annealing range within which grain growth, due to strain beyond the elastic limit, may be produced lies between 650° and 900° C. (1,200° to 1,650° Fah.) except in certain cases where it lies between 690° and 780° C. (1,275° and 1,435° Fah.). (4) When the applied strain falls below a certain or "critical" amount, the annealing range within which grain growth can occur seems to be limited by the thermal critical points at about 690° and 780° C. (1,275° and 1,435° Fah.). (5) The most practical standard by which to measure the strain applied seems to be the reduction of area. Experiments based upon such measurements show that no grain growth occurs following a reduction of area of less than about 7 per cent. or more than about 25 to 30 per cent. The "critical" strain mentioned seems to be marked by a reduction of area of about 9 per cent. (6) The refining action taking place at about 780° C. (1,435° Fah.) is a further indication of the presence of a thermal critical point at this temperature. (7) No serious grain growth was found in steel the carbon content of which was uniformly above about 0·15 per cent.

PRESSURE-REDUCING VALVE.

SOME improvements have recently been made and patented by Messrs. Sir W. H. Bailey & Co., Ltd., of Albion Works, Salford, in pressure-reducing valves for steam and other fluids. The accompanying sectional view shows a Foster patent reducing valve embodying the improvements which have for their object to render the valves quieter and smoother in action by obviating concussion and ensuring a more gradual and uniform passage of the fluid from the high to the low-pressure side of the valve. In the Foster reducing valve the pressure desired to be delivered to the heating or other system is set and automatically governed by an adjustable spring acting through a system of toggle levers on a diaphragm in the valve chamber; this diaphragm has a spindle passed through it and one end of the spindle is engaged by the toggle levers and the other end of the spindle carries a double-beat valve having two seatings in the valve body through which steam or other fluid under pressure is passed. The invention relates to a double-beat pressure-reducing valve of the above type and consists essentially in forming one of the double-beat valves as a sliding piston valve, whilst the other valve of the pair is of the usual bevel-edged type.

Referring to the illustration, B designates the inlet and C the outlet of the valve, E the diaphragm, F the valve stem, A D the double-beat valves, G the adjustable spring, H a nut on the screwed portion of the spring rod for regulating the delivery pressure, and J toggle levers acting in combination with links K. The valve A of the double-beat

valves is made in the form of a sliding piston valve, as shown, whilst the other valve D of the pair is of the usual bevel-edged lift type, by which means high-pressure steam is enabled to pass first through the lift valve D whilst the piston valve A remains closed until the delivery pressure



PRESSURE-REDUCING VALVE.

is reduced to such a point that the piston valve A is also opened and the steam or other fluid passes through both the double-beat valves in a greater volume, whereby "wire drawing" and any cutting action of the fluid on the valve face and seats is prevented.

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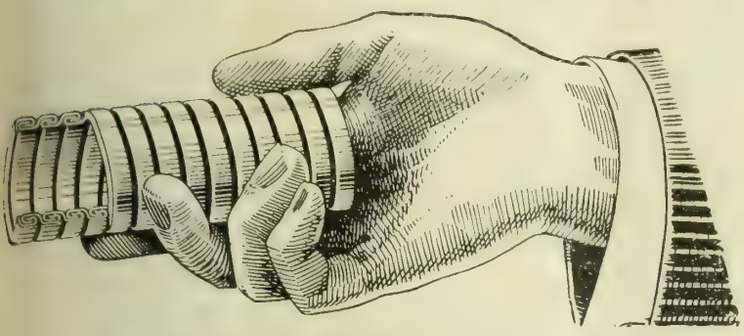

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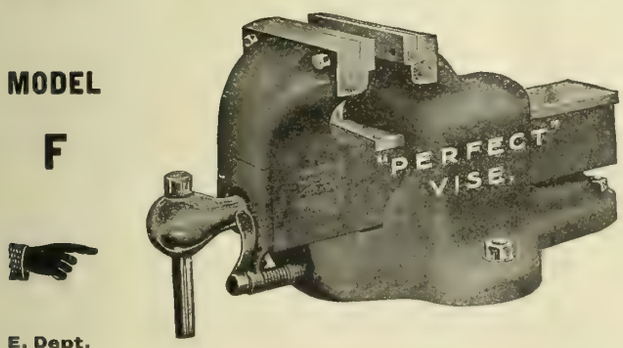

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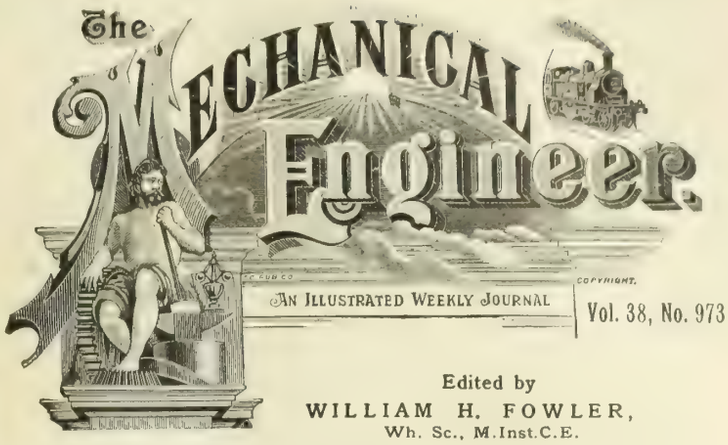

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Advertisements, displayed, for insertion in current issue should reach our Manchester office not later than first post Tuesday morning, and small prepaid advertisements not later than first post Wednesday morning.

The Revival of "Ca' canny."

THE resolution passed by the Trades Union Congress indicating the intention of the delegates to insist after the war on the restoration of all trade union "rights and privileges," in the shape of restriction of output, demarcation of labour, and other odious phases of the system of "ca' canny" so rampant before the war, should not perhaps be taken too seriously. The outlook on social questions and relationships of most of us has been materially altered by the war, and we do not suppose the trade union section of society has escaped the infection. At all events the delegates at the conference cannot pretend to speak for that large portion enrolled in the Army, whose feelings must have been seriously harried on many occasions during the last two years at the sight of fellow members in receipt of high wages and free from military restraint demanding further special rewards and conditions in return for service which they were rendering in fuller and more deadly measure in the trenches. There have been times when the action of trade unionists at home must have appeared to those in France very much like blackmailing. However, as we have said, we are not inclined to take the resolution too seriously. There will be many readjustments to make after the war—a great deal of give and take; and though peace between the Ministry of Munitions and many trade unions was only purchased by the Government on several occasions during a period of extreme war anxiety, by promises to restore, when peace comes, the hateful trade union regulations that prevailed, it must not be forgotten that when any adjustment is made public opinion will have to be taken into account, and that this opinion will not only embrace the changed feelings of soldiers returning to civil life, but also those of the large army of munition workers, both men and women, who have been recruited to manufacture the needs of the Army and whose labours have proved how easily

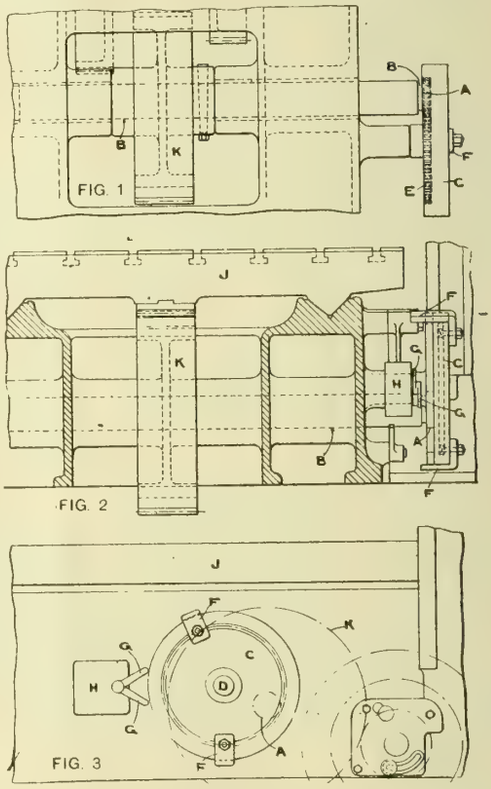
much of the reputed skill in the handling of modern engineering tools and machinery could be acquired, and, what has been even more striking, how greatly, when such labour was unfettered, the output could be increased. In view of this we do not think public opinion in the future will be so easily misled or so ready to accept trade unionists' estimate of their own importance. Democracy, in our opinion, will mean a great deal more in the future than it has done in the past, and any attempt of a minority of society to thrust its opinions and restrictions on the rest is likely to meet with prompt punishment. The wiser heads in the trade unions recognise this, and the assent of many of them to the resolution passed at the congress is, we believe, only an effort to save appearances for the extremists, who endeavoured to take advantage of a nation's extremity for their personal benefit.

Division of Profits Between Capital and Labour.

IN the course of his admirable address to the engineering section of the British Association, Mr. Gerald Stoney took occasion to illustrate the fallacy of the argument often employed by certain Socialists to sow discord between classes, that the division of the profits of engineering industry between capital and labour is grossly unfair to the latter. It has often been exposed, but there can be no harm in repeating it at the present juncture, when many attempts are being made to revive it in an acute form. The average capital expenditure per workman employed in an engineering works, according to an investigation made by Mr. Stoney some years ago, and since confirmed by a similar enquiry into shipbuilding yards, as well as by the Census of Production, is round about £200, while an investigation of the dividends paid shows them to be about 4 per cent. on the capital employed. It is true the dividend in the case of some firms is much more, and reaches 10 to 15 per cent., but they are often working with a large amount of preference or debenture capital at a much lower rate of interest, while against them must be set companies that do not pay any dividends at all, and of which, of course, nothing is said, for it is division of profits, not of losses, that is sought by these society equalisers. It may be taken that the average profit received by shareholders is, in round figures, £8 per year per individual employed, and the average wages for men and boys in engineering works in normal times is £70 per annum—at present it is no doubt much more—from which it will be evident that the worker gets between eight and nine times as much as the capitalist—not a bad proportion for sticklers for equality. The figures show how small is the margin of profit on enterprise secured by the capitalist as a rule, and is a thing to remember, for in the absence of profit capital will cease to erect works and seek more profitable outlets elsewhere. As matters stand at present every £200 invested in a factory in Britain means work and livelihood for one workman. The mutual mistrust with which many workmen and employers regard each other is a regrettable feature of present-day relations, and if Mr. Stoney exposes the fallacy of some of the arguments distilled into the ears of workmen by trade union agitators who have, by fomenting discord either between workmen and employers or between one trade union and another, he is equally outspoken respecting the disregard for workmen's comfort and convenience shown by many firms. Why, he asks, should Factory Acts be necessary to ensure proper lighting and ventilation? Why should shop sanitary arrangements often be a disgrace? Why should it be so rare to find a decent provision for the warming or obtaining of meals, or the drying of clothes? These are pertinent questions, and the arrangements that have been developed during the last two years to secure the welfare and comfort of workpeople in Government munition works shows not only how much more can be done to make workpeople's lives comfortable, but how much many employers have neglected to do so. We are a nation of workers, and seeing that the majority of us must spend the greater part of our lives at our respective tasks, there is no reason why we should not make them as agreeable as possible. It is not only common-sense but good business, for an efficient workman must first be a contented workman.

REVERSING GEAR FOR PLANING MACHINES.

THE accompanying illustrations show an arrangement of reversing gear for planing machines, the invention of Mr. J. G. Stirk, 25, Lentilfield, Ovenden Road, Halifax. Fig. 1 is a plan view of a portion of a planing machine bed with the gear applied. Fig. 2 is an end elevation partly in section of Fig. 1. Fig. 3 is a side elevation of Figs. 1 and 2. A small pinion A is mounted on the end of the bull-wheel shaft B. This pinion gears with a wheel C mounted upon a stud D and having internal or external teeth E. The wheel C has adjustably secured thereto dogs F which—as it is revolved by the pinion



REVERSING GEAR FOR PLANERS.

A—strike one of the arms G of a double-armed electric reversing switch H controlling the reversing mechanism, in the ordinary manner similar to that of the ordinary dogs, but at a much reduced velocity, and consequently with a correspondingly reduced shock. The wheel C may be indexed to give a direct scale reading of the stroke movements of the table J to facilitate measuring and adjustment of the stroke. For instance, if pinion A measures 3in. diam. on pitch line and bull-wheel K similarly measures 24in., a movement of $1\frac{1}{2}$in. on the pitch of wheel C is equal to 1ft. of traverse of the table, and a corresponding diagram set out or attached to the side of wheel or disc C may act in conjunction with the dogs F.

The Nottingham Society of Engineers.—The first meeting of the new session will be held at the Welbeck Hotel, on Wednesday, October 18th, at 7-30 p.m. The meeting will be devoted to the reading and discussion of short papers on engineering subjects, and members are invited to submit such papers, which should not take more than ten minutes to read. Six papers will be read, and members will then be asked to vote for the two best papers, so they can be discussed and prizes awarded. All papers should be sent to Mr. J. F. Chambers, The Elms, Daybrook, Nottingham, by October 2nd.

BOOK REVIEWS.

Theory and Practice of Modern Framed Structures. Designed for use of schools and professional engineers, by the late J. B. Johnson, C.E., C. W. Bryan, C.E., Chief Engineer of the American Bridge Company, and F. E. Turneaure, C.E.; in three parts. Part III.: Design. New York: John Wiley & Sons. London: Chapman & Hall. 9¼in. by 6¼in. 486 pp. Price 17s. net.

The design of framed structures has largely resolved itself into more or less standard forms, and differences, where they do exist, are mainly in matters of detail. It is difficult for writers of text books to present anything new, and such merit as they can claim individually must arise out of the description of the particular models taken as examples, and arrangement of subject matter. In this respect the volume under notice is entitled to a fair measure of compliment as a sound illustration of the details of American practice. The first seven chapters are devoted to a treatment of fundamental topics, which are then illustrated by the detailed design of several structures. These include a plate girder, a pier connected railway bridge, various forms of riveted trusses, a steel roof truss, and a steel building frame. In addition, there are several appendices, one giving the general specification of the American Engineering Railway Association, a second giving the most frequently used standards, and a third treating of the mechanics of unsymmetrical bending. The chief value of the book to students, for whom it is primarily intended, is the careful way in which details are illustrated and considered and the excellent series of plates reproduced from working drawings.

* * *

Water Powers of Canada. Published by the Department of the Interior, Ottawa, 1916.

This volume consists of a series of five monographs prepared by eminent Canadian water power engineers, and covering the actual and potential sources of water power in the various parts of this vast Dominion. They were prepared originally in connection with the International Engineering Congress in San Francisco in September last, but owing to the large demand they have been reproduced collectively. While not pretending to be a complete report on the water power of the Dominion, they cover fairly well and in a popular way the power which has been developed, and give information as to the method of administration in the various provinces, and to what officials communications should be addressed for further information by those who contemplate the founding of industrial enterprise. The volume is not only interesting to commercial men as a revelation of the potential power resources of this glorious colonial empire, but to the general reader for the idea it affords, through the medium of the photo views scattered through its pages, of the unrivalled beauties of its mountain and river scenery. No country in the world possesses such variety, and some idea of its industrial potentialities may be inferred from the fact that within the Dominion, and excluding the North-west territories, it is estimated that nearly 18,000,000 h.p. is available in its streams, and that of this vast total less than 1¾ millions have so far been developed, though this development, it should be noted, has practically taken place within the last 20 years.

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"The Journal of the Institute of Metals." (Vol. XV.) Edited by G. Shaw Scott, M.Sc The Institute of Metals, Caxton House, Westminster, S.W. 21s. net.

Corrosion matters dominate the latest issue of the "Journal of the Institute of Metals." Perhaps this is as it should be, for, since the last volume appeared, the Government have made a grant equivalent to £1,000 per annum to the Institute to carry on research work on this important subject. The present volume contains the third report to the Corrosion Committee, along with the discussion. In addition, there is a description of an electrolytic method of preventing corrosion, which depends on the application of a counter electromotive force. Among other papers are two dealing with aluminium and its alloys, as well as one on "The Annealing of Nickel-Silver," and another on "Electric Furnaces as Applied to Non-ferrous Metallurgy." In addition, abstracts are given of scientific papers from all parts of the world.

The Strength of the Webs of I-Beams and Girders. Bulletin No. 86. Engineering Experiment Station, University of Illinois.

For the purpose of studying the web strains in I beams and girders tests have been conducted at the Engineering Experiment Station of the University of Illinois on a number of specimens consisting of 12in. I beams having webs planed down to a thin section and 24in. built-up girders having webs of thin plates. The test data were used in conjunction with a mathematical analysis to determine the importance of the diagonal strains and the methods of failure of girders. The results show (*a*) that, in general, the shearing stress is a maximum at the neutral axis, but that diagonal stress at the junction of web and flange must be considered, (*b*) that approximate methods of computing shearing stress in webs should, under certain conditions, be checked by more exact methods, (*c*) that stiffeners at supports and under concentrated loads are very necessary, and (*d*) a formula is developed for the buckling strength of webs. The investigations were conducted by Prof. H. F. Moore and Prof. W. M. Wilson; and copies of the Bulletin may be obtained on application to W. F. M. Goss, Director, Urbana, Illinois.

BOOKS RECEIVED.

Ruler and Compasses. By Hilda P. Hudson, M.A., Sc.D. London: Longmans, Green, & Co. 7½in. by 5in. 143 pp. Price 6s. net.

Earth Pressure Retaining Walls and Bins. New York: Wiley and Sons. London: Chapman & Hall. 9in. by 6in. 287 pp. Price 10s. 6d. net.

Arithmetic for Engineers. By Chas. B. Clapham. London: Chapman & Hall. 8¾in. by 6in. 435 pp. Price 5s. 6d. net.

Gas Engine Ignition. By Earle B. Norris, M.E., R. K. Winning, B.S., and W. C. Weaver, B.S. New York: McGraw Hill Book Company. 9¼in. by 6¼in. Price 6s. 3d. net.

Gas, Oil, and Petrol Engines. By A. Garrard. London: Whittaker & Co. 7½in. by 5¼in. 220 pp. Price 5s. net.

Fire Protection for Passenger Ships. British Fire Prevention Committee Report, No. 203. 8½in. by 5½in. 44 pp. Price 3s. 6d.

Applied Mechanics and Mechanical Engineering. By Andrew Jamieson, M.Inst.C.E. Edited by Ewart S. Andrews. Vol. I. Applied Mechanics. 10th edition. London: Chas. Griffin & Co. 8in. by. 5in. 371 pp. Price 6s. net.

Masonry Dam Design. By C. E. Morrison, C.E., Ph.D., and O. L. Brodie, C.E. 2nd edition. New York: John Wiley & Sons. London: Chapman & Hall. 9in. by 6in. 276 pp. Price 10s. 6d. net.

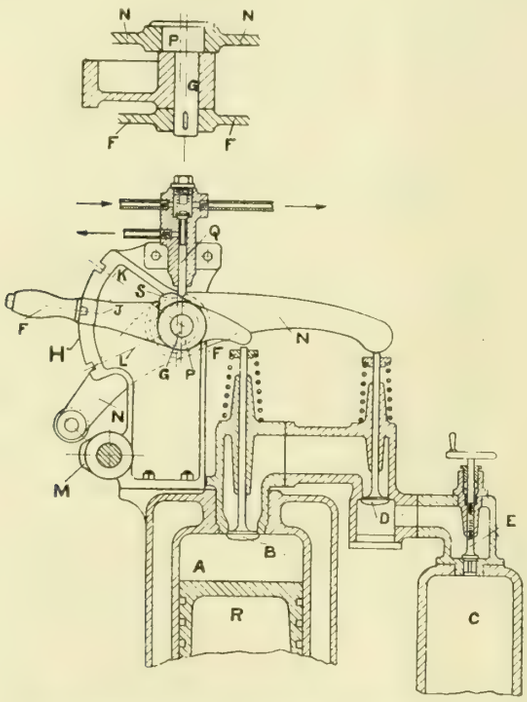
STARTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

An arrangement for starting internal-combustion engines by means of compressed air, the supply of the latter in the compressed air receiver being replenished, when required, by the engine itself charging the air receiver by delivering compressed air into it from the power cylinder during the compression strokes of the engine piston, has recently been patented by Messrs. Crossley Bros., Ltd., Openshaw, Manchester, Mr. Wm. Huskisson, and Mr. L. F Barley.

The arrangement is shown in the accompanying sectional views applied to an oil engine, the cylinder being shown at A, cylinder retaining valve at B, compressed air receiver at C, air receiver retaining valve at D, air receiver stop cock at E, hand lever at F keyed to the fulcrum pin G, a notched quadrant at H, the "inoperative" position of the hand lever at J, "starting" position at L, and "charging" position at K, an engine-operated cam at M, cam-operated lever at N oscillating on the eccentric fulcrum P, fuel valve at Q, engine piston at R, and cam-shaped projection S on the hand lever.

When the apparatus is not in use the hand lever is placed in the "inoperative" position J as shown and the stop cock E

is closed. When the engine is to be started the stop cock is opened and the hand lever F is moved into the "starting" position at L, and, owing to the lever N being mounted eccentrically to the pin G on the fulcrum P, this brings the one end of the lever N in contact with the cam M, the other end of the lever opening the valve D, thus admitting compressed air from the receiver C through the valve D past the valve B (the latter becoming self-acting in action) into the cylinder A and imparting an impulse to the engine by forcing the piston R outwards on each working stroke until the hand lever F is moved away from the "starting" position, or until the air from the receiver is exhausted, or until the stop cock E is closed. When the engine is working and it is desired to replenish the supply of compressed air in the air receiver the stop cock E is opened and the hand lever is moved over to the "charging" position, thus opening the cylinder retaining valve B. The air compressed in the cylinder A on the compression stroke then passes out of the cylinder through the valve B, air receiver retaining valve D (the latter becoming



STARTING APPARATUS FOR INTERNAL-COMBUSTION ENGINES.

self-acting in action), and stop cock E to the receiver C. As soon as the supply is sufficiently replenished the stop cock E is closed and the cylinder retaining valve is closed by moving the hand lever F back to the "inoperative" position.

While charging the receiver from the air compressed in the cylinder it is desirable to prevent the admission of fuel to the engine and this is done with the hand lever F so that one operation both opens the cylinder retaining valve and also prevents the admission of fuel to the engine. The oil fuel valve Q is lifted off its seat by the cam-shaped projection S on the fulcrum boss of the hand lever when the hand lever is moved to the charging position. In this case the oil fuel is normally passing across the head of the valve Q, say to a sprayer, under pressure from a pump, but when the valve Q is opened the oil is by-passed through the valve to the lower opening shown and thence to the oil supply reservoir, thus preventing it being admitted to the engine.

CARE OF LOCOMOTIVES WITH RELATION TO FUEL ECONOMY.*

BY A. N. WILLSIE.

MUCH is expected of a locomotive; it is called upon to do more work and stand up to more punishment and lack of care than is economical from the fuel standpoint. Every delay, every piece of careless or indifferent work on the part of road or shop or roundhouse men, every neglect of machinery, boiler, or flues reverts back to the coal pile.

Boilers.—The boiler capacity of a locomotive should be ample over the cylinder volume, as it cannot be 100 per cent. efficient all the time. This is true for several reasons, such as the condition of the fuel, which varies as to weathering, slack and non-combustible material, condition of water, condition of boiler and flues, inexperienced firemen and men newly promoted to the position of engineer. All of these tend to detract from the desired 100 per cent. efficiency. The boiler is required to furnish steam, not only for the cylinders, but is also called upon to furnish steam for much other work.

Air Compressors.—Oftentimes from 10 to 15 per cent. of the entire coal consumed on a trip is used to generate steam which is used by the compressors. This is not always realised. Air compressors should be equipped with the proper kind of strainers to protect the air intakes; the best is none too good. Arrangements should be made so that it is possible to lubricate the air end properly. This item is badly neglected on many roads, and with bad results. The old-style strainers have holes knocked in them with any convenient tool, and then oiling takes place through the air intake, which is very bad; this also allows just that much more foreign substance to be pulled into the compressor and discharged through the main drum, and back through the feed valves, brake valve, and other parts. There should be no traps in the steam line between the supply valve and governor, or between the lubricator and the steam line leading to the compressors, and yet this often occurs. Another important factor is to see that the proper sizes of pipes, valves, and governors are used for the different sizes of compressors; this refers more especially to engines that have had larger cylinders put on with a reduced boiler pressure, and in some cases two compressors being installed instead of one.

The air compressor exhaust should be located so that the steam will not go directly up the stack, as when standing this creates a terrific draught on the fire, giving the same effect as a strong blower and resulting in a great waste of coal. A good plan would be to have every engine equipped with a 2-way valve, controlled from the cab, so that the pump exhaust could be turned into the tank, when so desired. This would take all the draught away from the fire, if used when standing, and would heat the water in the tanks, resulting in a saving of coal to the amount of 1 per cent. for each 11° of increased temperature. The water can be safely put up to 90° or 100° without any trouble whatever as to the working of the injectors. As the average temperature of the water is probably about 55° or 60°, the saving made possible by using this waste heat from the pump exhaust is worth caring for.

Radiation, Steam Line to Air Compressors.—"Steam Power Plant Engineering," by G. F. Gebhart, Professor of Mechanical Engineering of Armour Institute, is quoted as follows: "For most practical purposes the loss of heat from bare steam pipes or drums may be taken at 3 B.T.U. per square foot of heating surface per hour per degree difference in temperature of steam inside and air outside." The average difference between air temperature and steam at 200lbs. pressure may be taken as 322°. Twenty feet of 1½in. pipe expose 20 sq. ft. of surface. As there are 8,760 hours in a year, an engine may be assumed to be under steam at least 3,000 hours per year. Assuming that the coal used has a heating value of 12,000 B.T.U. and that the engine has an efficiency of 60 per cent., the loss per engine will show 9,660 B.T.U. per hour, or 28,980,000 B.T.U. per year, which is the equivalent of 4,025lbs. coal. This does not cover all the loss, as condensed steam or water entering the steam end of the compressors is much less efficient, ruins the lubrication, and in time more waste occurs by cut valves, valve seats, and the pistons of the compressor.

Radiation of Boiler.—From tests made by Dean Goss several years ago on a small engine with 61 per cent. of the boiler covered, the loss standing was 18lbs. of coal per hour, the air temperature being 80°. The loss at 28·3 miles per hour was 37lbs. of coal per hour. On same boiler with no covering the loss standing was 48lbs. of coal per hour and at 28·3 miles per hour was 100lbs. of coal per hour. This gives an idea of the importance of keeping the boilers well lagged, and also of getting them out with the least terminal delay.

Scale.—There seems to be a variation of opinion as to the

* Paper read before the International Railway Fuel Association.

losses due to the accumulation of scale in boilers. Some of the best authorities give the approximate losses as shown in the following table:

Thickness of scale:	1/64	1/32	1/16	1/8	3/16	1/4	3/8	1/2	5/8	3/4
Per cent. loss of heating power:	2	4	9	18	27	38	48	60	74	90

These figures are not considered absolutely accurate, as these losses are not found to occur in all boilers, because the whole of the boiler surface does not usually become covered; still the loss is always serious, apart from the stresses set up in the boiler plates. A test was made by Prof. Breckinridge, of the University of Illinois, on a mogul freight engine, which had been in service for 21 months. This engine, after being tested, was then sent to the shops and new flues installed and again tested, the same as before. In order to get the average thickness of scale, it was entirely removed from the tubes and weighed. This thickness gave an average of 3/64 of an inch over the principal heating surface, and showed a loss in heating power due to the scale of 9·55 per cent.

Soot.—The writer has been unable to obtain any reliable data as to the percentage of loss due to soot in flues on locomotives, but holds to the opinion that the amount of soot that will adhere to the inside of a flue will cause as much loss of heating power as $\frac{1}{64}$in. scale on the water side of flue, or 2 per cent., and any ash accumulating in the bottom of flues causes still a greater loss, according to the area covered. Boiler trials conducted by the engineering department of the University of Illinois show that as between having the tubes cleaned each morning and allowing the soot to remain on the tubes, there can be effected an increase in evaporation due to clean surfaces, 13 per cent., a decrease in coal burned per square foot of grate per hour of 32·16 per cent., and a lowering of stack temperature of 17·59 per cent. Prof. Ordway, in the "Transactions of the American Society of Mechanical Engineers" (Vol. VI., page 168), shows that there are only two materials that rank higher than soot as non-conductors of heat. The first is loose wool; the second is live geese feathers. Asbestos is thirteenth on the list. One would not think of covering boiler tubes with asbestos, but on the other hand, we seem to think very little of coating our boiler tubes with soot and ash; and yet, thickness for thickness, soot will stop five times as much heat as fine asbestos.

Washing.—A boiler should be washed regularly, using hot water with a pressure of about 100lbs. Begin early and keep at it, and do not allow accumulations of sludge. Nothing is gained by trying to get too many miles out of an engine between washings, as the foul boiler results in water being carried over into cylinders, ruining lubrication and packing, while at the same time the mud and scale in the boiler reduces the rate of heat absorption.

Draughting.—After the boiler has been put and kept in first-class condition, the next important step is proper draughting. This includes nozzles with free and unobstructed opening of as large an area as is possible for good steaming. Engines should be draughted and grated for the coal that is to be used, and the same grade of coal should be supplied as far as practicable. In this way the crews become familiar with the best way to handle the coal, and the engines will burn it more economically. The centre of the nozzle must not only be plumb with the centre of the stack, but it must be level, otherwise the exhaust steam will not properly fill the stack. There should be no ragged edge of smokebox shell where the stack is fastened on. In order that the nozzle and front end may perform their functions, the flues must be kept clean and dry, and no leaks must be allowed in the steam pipes, dry pipe connections, or in nozzle stand seat. Special attention should also be given the running of nozzles with as large openings as possible, for the reason that with reduced nozzle openings the temperature of the superheated steam in the cylinders gets so high that it is injurious to the lubrication and piston-rod packing, making it difficult to prevent the packing from melting. When an engine begins to lag on steam, reducing or bridging the nozzle should be the last resort; the trouble is usually some place else.

Water Losses.—A total leak of but one pint per minute is 180 galls. per 24 hours. One hundred and eighty gallons per day is 65,700 galls. per year. As these leaks occur whether engine is under steam or not, full time, 24 hours per day, has been figured. One pint per minute is a very small leak, taking into consideration the leaks around tank, tank hose and injector overflows, &c. About 20lbs. of water is necessary to prime a non-lifting injector, but often several times this amount is used, due to neglect on the part of the crew, and then additional waste after the injector steam valve is closed. Another bad waste is carelessness in filling tanks; they often overflow to the amount of 100 galls. or more. While an overflowing tank has nothing to do with maintenance of the engine or tender, it represents a loss, just the same, and a coal loss in cases where coal is burned under pump house boilers.

Steam Leaks.—If steam leaks were the same (1lb. or one pint per minute), and assuming the engine was under steam one-third of the time, the waste would be 65,700 galls., divided by three, which equals 21,900 galls., or 182,500lbs. of steam; this divided by five, equivalent evaporation, gives 36,500lbs. of coal. This waste is liable to occur in leaky pops, surface cocks, valves in cabs, injector throttles, blowers, steam heat valves, and main throttle of engines. All steam leaks must be avoided.

On engines in freight service equipped with train-heating apparatus the steam valve in the cab is usually cracked a trifle to allow some circulation to avoid the line freezing up; this soon cuts the seat, and then it is impossible to close the valve tightly. On engines in this class of service a small by-pass valve may well be used, so that circulation may be possible with no injury to the main and reducing valves. The expense of grinding in the small valve will amount to nothing compared with the other valves. The main throttle must be kept tight, as a matter not only of safety but economy. The waste is very bad with leaking throttle, as can be evidenced by observing the condensation and blowing at cylinder cocks. Steam joints in front end should be tested every 30 days. Leaks in front ends of superheater engines can be so bad that no superheated steam reaches the cylinders, yet the engine may work along, doing nearly as well as a saturated engine. If such leaks occurred with a saturated engine there would be a complete engine failure. Simmering flues soon honeycomb the sheets, reduce the heating surface and waste coal. Honeycomb must be removed from all parts of the firebox, but is often left on crown staybolt heads.

Grates.—Grates must be kept in good condition, so that they will work freely, and there should be no unnecessary openings, such as at broken fingers; they soon allow a hole in fire, with loss of fuel going to ash pan, which is a waste and injures the pan, and also allows too much free air, resulting in poor combustion and possibly leaky flues. If the grates work hard the fireman puts the job off as long as he can, resulting in heavy fires and waste of fuel. Grates should be shaken only when necessary, and not too hard. They should be shaken only when the engine is standing or drifting, this to avoid tearing holes in the fire.

Arches.—Arch tubes should be used. This not only gives more heating surface, but makes it possible to get much more mileage out of the arch brick. Arches supported on studs do not last nearly as long, and when one brick goes down, at least one more (the opposite) goes with it, then the trip is continued with an arch of improper dimensions, resulting in loss of fuel. The saving in coal by use of an arch is not all due to the arch itself, as by the use of an arch the fireman is compelled to do a better job of firing than he might possibly do were there no arch in the firebox, he being compelled to fire lighter and more often; and there will not be so many "conversation fires." The maintaining of a good arch of the proper height reduces a great deal of the front end losses, which are greater than generally considered; these front end sparks contain 25 to 40 per cent. carbon and upwards of 12,000 B.T.U. per pound.

Fire Doors.—Fire doors should be kept in good condition. With pneumatic doors the air connections should be kept tight, and the deck so maintained that the fireman can operate

the tripper conveniently. If the old style swing door is used the chain should be hung properly, so as not to bother the fireman. It should be just long enough, but not so long as to wrap around door latch or other projections on boiler head. The catch to hold the door open must be so arranged as to catch the door each time, otherwise it is very difficult to get the fireman to swing the door between each two shovelfuls of coal.

Tender Design and Maintenance. Decks of engines must be kept tight with no openings around the pin holes or shaker levers and other places. A loss of 200lbs. per trip through such openings is very conservative with the average fireman. The same with decks and tanks; and the shovel plate should be smooth, with no seams or rivets. Tanks should be built so that coal will be kept within easy reach of the fireman. There should be guards to prevent coal working out of the gangways. The coal gates should be so constructed and maintained as to prevent the loss of coal. The same applies to the construction of the tank. Usually the coal space is longer than it is wide; if so, the tail boards should be higher, or shaped to conform to the crown of the pile of coal on tender. The tendency is also for the coal to work forwards and backwards more or less, on account of the jar of coupling on to cars. The manhole on tender should be as long as allowable, so that the water crane spout will fit. Even if the engine is not spotted directly opposite, this saves delay, which saves coal and also saves water and time in filling the tank. If the tank has a small manhole and the engine does not stop in proper position to take water there is a delay, and steam is used in moving forward or back.

General Remarks.—Roundhouses and their surroundings, such as good coal chutes, clinker pits, and turntables, all go to help maintain the engines and save coal. If the engine cannot get into the house it cannot be given proper attention, especially as to flue cleaning. Just being allowed to thaw out in the winter time helps considerably. If the required work cannot be done, the engine makes another trip or more and uses more coal than it should. Stacks should be covered while in the house, to save heat and save flues, and the boiler will hold steam much longer. If an engine is kept in good condition it is not only possible for it to do better work, but it encourages the engineer and fireman to do better work. When they are able to handle the trains faster the conductors and brakemen naturally get into the game, also the dispatcher, with the result that the crews are on the road less time, saving time and overtime, all of which saves coal, if the engine is not worked beyond the economical point. Lack of attention to rod and journal bearings soon results in heated bearings.

Engineers and Firemen.—Engineers and firemen can help a great deal toward maintaining the engine, to save coal while in their charge, as well as handling the coal economically while on the trip. Co-operation and harmony must exist. Have the fire and water of proper level before starting. Start the train carefully; avoid slipping and raising of water; use the steam expansively; take advantage of the grades; work the engine no harder than is necessary; work full throttle as far as practicable, using the reverse lever to control the power required. Proper firing and pumping are very essential. This will place the engine on clinker pit track with a good head of steam and plenty of water and fire, in such condition as to require but little delay in getting the engine into the house.

Co-operation.—The engineers, firemen, trainmen and dispatchers, shop men and roundhouse forces, the chief dispatcher, yardmaster, and roundhouse office must work together. Avoid all the terminal delays possible, giving the mechanical department the benefit of every hour allowable to put engines in condition. Have an understanding as to when the engine will be needed, as the mechanical department can often take advantage of this time to do work which could be put off; but in allowing this the repairs to be made would be more expensive later on, and in the meantime more coal would be used.

General Officers, Both Operating and Mechanical.—These officers should do everything possible to get good roundhouse facilities and terminals, otherwise the engines cannot get the care they need. Delay in getting to the house is often caused by coal chutes, clinker pits, and turntables being inadequate. The roundhouse is sometimes too small and not properly lighted or heated, and the stalls so short that engines cannot be placed inside and the doors closed. Poor steam and air plants and tools all go to prevent proper maintenance, consequently a loss of fuel. The operating department should not order engines till needed, and then should get them over the road in the least time possible, according to the work required of them. Engines can be overloaded and worked beyond the economical point of combustion, resulting in heavy maintenance and also waste of coal.

INSTITUTE OF MARINE ENGINEERS.

PRESIDENTIAL ADDRESS.

AT the opening meeting of the new session of the Institute of Marine Engineers, Sir James Mills, K.C.M.G., in his presidential address, dealt with the general relations between shipowners and engineers, and the importance in the national interests of maintaining a high standard of ability and character on the part of marine engineers, as follows:—

As a shipowner I am naturally interested in the developments of marine engineering, but my interest is that of a business man rather than of an engineer. It is true that the aim of both the shipowner and the engineer is to secure the highest efficiency, but you will recognise that the shipowner must take into account many questions which do not come within the province of the engineer. One can easily conceive the production of a type of machine which from a strictly technical point of view might be a triumph of marine engineering, but which considerations of business policy would not allow the shipowner to adopt. In such case the inventor is apt to be impatient with the shipowner, who, while not unsympathetic, is compelled to turn down his invention as unsuitable for practical business purposes. Reverses of this nature, however, only stimulate the inventor, who is on the right track, to set his wits to work to overcome whatever objections may be pointed out to him.

The respective functions of the engineer and shipowner are never antagonistic; on the contrary, the progress of shipping largely depends upon the skill, resource, and general efficiency of the engineering profession, and I take it that at no time were these qualities more conspicuous than they are to-day. Each, however, has his own special sphere, and it is only by a successful combination of the two spheres that the maximum advantage can be secured. It is with the broad business aspects of the industry that the shipowner is mainly concerned. While keeping pace with the requirements of his time he must also anticipate developments and be prepared to take such risks as may be reasonably incurred. He is usually in the position of a trustee for shareholders, and he is called upon to exercise constant prudence and watchfulness in order that their interests may be conserved. At the same time he is fully conscious that without the harmonious co-operation of the various sections of skilled and unskilled labour connected with the business of shipping the best results cannot be obtained. In normal times, when a reasonable return on capital can only be secured by the utmost economy both in first cost and in working expenses, he looks to the engineer to secure for him the best results in both respects. He must also take into sympathetic consideration the interests of his employés, and be prepared to deal equitably with reasonable demands for conditions which lead to their comfort and security.

I need scarcely remind you how important it is in the national interests that the Empire should maintain her supremacy in shipping matters. This has been brought home to us with special force since the outbreak of war. The insular position of England, her dependence on outside sources of supply, and the vital necessity of maintaining regular communication with her overseas dominions, have been thrown into clear relief and made apparent to the least imaginative among us by the events of the last two years.

It is difficult to forecast the position of British shipping after the war, but it is clear that we must be prepared for entirely new conditions. The practical control by British shipping of the seaborne commerce of the world will no longer

remain unchallenged. The war losses, in addition to ordinary marine casualties during the last two years, have so seriously depleted our mercantile tonnage, while the output of fresh tonnage has been on so limited a scale, that it will be years before we can hope to enjoy the same relative advantage in regard to the tonnage of the world that we possessed before the outbreak of war; and we must recognise that, side by side with our depletion of tonnage, there has been great activity in the shipbuilding yards of neutral countries, so that we shall find ourselves challenged at every turn by well-equipped competitors. To meet the new situation we shall require not only ships equal, if not superior, to those of our rivals, but we must also be in a position to employ our tonnage to the very best advantage and with the greatest possible economy. It is obvious that the continuance of our supremacy as a maritime power will depend in no small degree upon the character and efforts of our engineers, whether they be designers, manufacturers, superintendents, or that fine body of seagoing engineers whom I have more particularly in mind to-night.

I am glad to have this opportunity of paying my tribute to the high qualities of the members of your profession. The nature of their occupation renders them liable to special risks, and we who live at home at ease realise the debt of gratitude which we owe to those who so coolly and courageously accept those risks. I do not of course overlook the claims of other branches of the mercantile marine who have done such magnificent work during the war, but I may be pardoned on an occasion like this for dwelling more especially upon the part which is played by the engineers. The records of shipping abound in instances where a steady nerve, a cool head, ready resourcefulness and skill on the part of engineers have averted loss of life and property; or where, disaster being inevitable, they have stood to their post with serene courage and steadfast devotion to duty.

I might here recall two examples which illustrate the resourcefulness and determination of engineers. One is the case of the "Southport." You will remember that this steamer arrived in the German Caroline Islands on September 4th, 1914, those on board being unaware of the outbreak of war. While the master was ashore a German cruiser came to anchor in the harbour and took possession of the British ship. The original intention of the Germans was to sink their prize, but they contented themselves with disabling her engines. The cruiser left the harbour three days later under the impression that the "Southport's" engines were completely out of action. They did not, however, bargain for the resourcefulness of the engineer on the British steamer. He, with the knowledge that the cruiser might return at any moment, at once set to work to repair the engines, and with such success that by the 15th the repairs were completed and the vessel steamed at low speed out of the harbour and eventually reached Brisbane safely.

Another example of still more recent date was that of the "Pukaki." The case is fully reported in the July number of the "Marine Engineer," and it is of special interest to me, as the steamer in question at one time belonged to the company of which I am chairman, and with which I have been associated for over 40 years. The "Pukaki" was trading in the Pacific, and on the occasion referred to was on a voyage through various groups of islands with Kanaka passengers When nearing her final port the shaft broke and the engines were of course stopped. On investigation it was found that the propeller shaft had parted in the stern tube, the propeller being up against the rudder post, where it had to be secured by slings to save it from loss or damage. The stern tube proved to be intact and the breakage was found to be in the fore end of the after liner, so that the use of Thomson's coupling was out of the question. The engineer, however, was fully equal to the occasion. Gear was rigged and the forward end of the shaft drawn into the tunnel. The gland, being about 4ft. below the water line, had to be made water-tight. Arrangements were made to tip the ship by means of shifting coal and filling forward tanks. When everything possible had been done in this direction the stern tube was still under water; but the engineer was not daunted, and gear and tackle were prepared and the propeller slung. Stopper and nut were removed, the boss was then turned round to get the key on top and the end of the shaft set up against the rudder post. The anchor stock was requisitioned for ramming off the propeller, angle irons and wedges being fitted at the fore end of the boss between it and the stern tube to assist the ram. It was difficult to get a fair blow with the anchor stock, two blade nuts and a stud being damaged in the process. The broken shaft was then got on deck, and tackle rigged on the derrick aft, by means of which it was slung over the side and brought to bear on the boss. After many difficulties the propeller was displaced, amid the cheers of the onlooking passengers. The outer broken end had now to be got into the tunnel, and this was no easy matter. Hauling in gear was fixed up and connected to the winch and the shaft end was pulled in so far and stuck; on being pushed back and the tube examined it was found that a loose broken piece of the shaft had caused the obstruction and on its removal the captured end was successfully drawn into the tunnel. A new difficulty and a great disappointment to the chief engineer now presented itself, in that the spare shaft was found to be too large in the tapered end, and that the keyways were uncut and no keys ready. By means of chisel bars and cross cuts the taper was made right to templets and filed up, and keyways cut and keys forged from an old valve spindle. At this stage and while repairs were still under way, negotiations were opened with a steamer brought within hailing distance by signals, as provisions were getting scarce and all hands, including the Kanaka passengers, were on short rations. However, the rate demanded for towage was considered excessive, and beyond supplementing their slender stock of provisions by some bags of rice and flour from the hailed steamer, they did not avail themselves of her services, and the engineers again set to work.

The spare shaft was now run through the tube, the propeller shipped on and the nut screwed up, then hammered home. The shaft was coupled up, and as the bolt holes were small, involving a good deal of time and labour in boring and rimering, this was dispensed with and temporary bolts were prepared and fitted aft into the propeller shaft, the larger holes in the tunnel shaft coupling being made up with wedge pieces around the bolts. The holds and tank were now pumped out, steam raised, and the "Pukaki" steamed off at the rate of seven knots to her port of destination, Rabaul, on March 11th. I think you will agree that this is a remarkable instance of an engineering job being successfully carried out under conditions of exceptional difficulty.

It must be recognised that developments are taking place almost daily in marine engineering which will call for the highest qualifications in those who are responsible for the care and direction of machinery, so I would urge, particularly upon our younger members, the importance of study and self-improvement, in order that they may educate themselves up to modern conditions, and have the necessary qualifications for the responsibility which awaits them. There are some who think that the State might well offer more encouragement in connection with the advancement of technical knowledge, while the fact that our engineers are at a disadvantage in this respect compared with the engineers of other countries, should serve as an additional stimulus to individual effort. There is a wide field open for both original work and the improvement and perfecting of present machinery.

In the period covered by my own business life there has been enormous progress in the science of marine engineering. In 1875, when my company came into existence, the triple-expansion marine engine was comparatively unknown, though this was about the time of its inception. It was not until about 1881 that the triple-expansion engine really claimed serious attention, and as a machine for marine propulsion it has had a truly wonderful vogue. To the majority of the members of this Institute the triple-expansion engine must have been more or less of a life-long companion. For certain services I have seen the triple-expansion engine developed into the quadruple-expansion engine, in which form the reciprocating marine steam engine has apparently reached its highest commercial development, and the excellently-designed balanced engines of this type have, for the last 20 years or so, given that high satisfaction which continues to mark their performance, particularly in respect of economy, reliability, and low maintenance cost on long voyages.

After the balanced quadruple-expansion engine came the direct turbine with its entirely new application of steam as a propelling power; then we had the combination of piston engines with the turbine; and the still larger development of an all turbine drive, securing the advantage of slow-speed propellers by the interposition of mechanical gearing. In

this very latest example the use of geared turbines has been combined with the employment of water-tube boilers and superheated steam, thus presenting in a merchant ship a machinery installation closely analogous to what is provided in H.M. cruisers. Even in respect to what is known as the geared turbine we seem to be on the eve of a still further development in the shape of double reduction gear, which has been used in the Navy, and is now about to be applied in the case of merchant ships.

Another departure of comparatively recent years is the use of liquid in place of solid fuel, which appears to give a remarkable increase in steaming capacity and still more remarkable diminution in the difficulties of stokehold management. I should say that all marine engineers would wish earnestly for conditions involving the wider employment of fuel oil, with corresponding improvement in the conditions of stokehold work at sea. But perhaps the most remarkable development of modern times is that of the internal-combustion engine. We have seen—in the submarine for example—the high utility of this motor, where reliability can be associated with the remarkable economy in weight of fuel which characterises the Diesel system. This type of marine engine for commercial purposes has already been fairly well tested in ships of moderate capacity, and we look forward to the advent of the vessels of larger size and greater power which are now being built to provide a convincing test of what can be done in the way of high power in a commercial engine of this type. It seems fair to assume that if the anticipations of the builders of the ships of this class are realised, we may expect within a very few years to see steam-driven vessels take a secondary place among the mercantile navies of the world.

Whatever revolutionary changes may be made in the future, I am satisfied that in the competition for the most efficient and economical forms of machinery for both naval and mercantile ships British engineers will lead the way. It must not be supposed that I under-estimate the difficulty of the task that lies before you. I realise that for its successful accomplishment it will require keen, fertile brains, the desire of knowledge for its own sake, the power of applying the results of theoretical study and experiment to practical requirements, and steady and persistent effort. It is a comfort to know that you would not be engineers if you were discouraged by difficulties. One of the best results of your training is that you are prepared to tackle troubles as they arise, and that no engineer who is worth his salt will be baffled by any obstacle that human effort and ingenuity can overcome.

Let me, in conclusion, say a word on the necessity for effective co-operation on the part of engineers. As a nation we have not in the past given sufficient attention to the systematic organisation of our immense resources in men and material, and in this respect at all events we have much to learn from the Power which is responsible for the present upheaval, and is now displaying, in its conduct of the war, such a cynical disregard of the laws of common justice and humanity. Without proper organisation there is bound to be a waste of efficiency, and it is one of the aims of this Institute to see that the various activities connected with marine engineering are organised in such a way as to secure the best possible results. I trust that the admirable work of this Institute may receive the practical and generous support of all who are interested in the progress of marine engineering and the welfare and improvement of British marine engineers.

THE INCREASING USE OF POWDERED COAL AS FUEL.

A QUARTER of a century ago numerous inventors worked on the problem of using powdered coal as fuel, and some of them achieved a fair degree of success. The advent of cheap fuel oil about that time, however, prevented the invention from being successful commercially except in the field of cement burning. Here the use of powdered fuel was a very important factor in the success of the rotary kiln. It effected a large reduction in the cost of burning compared with the fuel oil which was used at first. The use of powdered fuel for other purposes was abandoned until three or four years ago, when it was successfully applied to metallurgical furnaces. Since then the use of powdered coal has been experimented with in various other directions, notably as a locomotive fuel.

Those responsible for the use of powdered coal in the cement industry early learned, through some very costly and fatal accidents, that certain precautions were necessary in its use to guard against disastrous explosions. When it is recalled how frequently bituminous coal in place in the mine gives off inflammable gas, it can readily be understood that when bituminous coal is ground to an impalpable powder it is much more likely to give off a gas, which mixed with air in any confined space only needs a chance spark to produce a heavy explosion. Fine coal dust itself when floating in the air is also well understood to be a dangerous explosive. Further than this, any considerable bulk of powdered coal held in storage for a few days is apt to develop spontaneous combustion.

At the recent Master Mechanics' Convention, Mr. Chambers, who has been in charge of experiments with powdered fuel on a locomotive on the Chicago and Northern Railway, declared that it was not safe to store a quantity of powdered coal exceeding 10 to 15 tons longer than three or four days at a time. Anyone familiar with the chemical constitution of coal will readily understand that its liability to spontaneous combustion when powdered will vary greatly with different coals. If a consignment of coal happened to have an especially large percentage of pyrites in it, someone might be disagreeably surprised at the rapidity with which it would develop heat after being ground.

The question was raised in the discussion as to what a railway would do should it adopt powdered fuel for general use on its locomotives. At large railway coaling stations it is common to deliver to locomotives 2,000 tons or more of coal in 24 hours. The answer to this question is that in handling powdered coal the thing to do is to avoid storage as much as possible. Coal-pulverising machinery should be of sufficient capacity to handle the coal as fast as it is used, with a sufficient margin for extraordinary demands and for breakdowns. A minimum storage and no dust are the standing rules that must be observed to obtain safety in the use of powdered coal.

Many have predicted the commercial failure of powdered coal-burning systems on the ground that present methods of using coal are so efficient that any increased saving in fuel through pulverising will be more than offset by the cost. The advantages from the use of powdered coal, however, come from other sources than a mere increase of efficiency in burning the fuel. Those who are promoting its use in locomotives, for example, hope to make the powdered coal-burning locomotives so free from smoke and sparks that they can be used inside city limits for switching locomotives to offset the public demand that the railways shall expend enormous sums for electrification, in order to get rid of locomotive smoke. Locomotives burning powdered coal could also be used in forested regions where the railways are now in some cases compelled by public authorities to burn oil fuel to avoid the risk of setting fire from scattered sparks.

Probably the greatest field for the burning of powdered fuel, however, will be in aiding the economical utilisation of fuels, such as lignites, which are difficult to burn efficiently by ordinary methods. Some lignites contain nearly 50 per cent. of volatile matter and have shown remarkably good results as a fuel for gas producers and as a material for briquettes. The cheapest way to use this fuel, however, is in the form of powdered coal. The high content of volatile matter is especially favourable to firing in this way. Another fuel which seems capable of use in powdered form is peat. Sweden, which has no coal deposits, possesses large peat bogs. A recent report of the Department of Commerce states that the Swedish State Railways have been experimenting with powdered peat as fuel for locomotives, and the railway directors have recommended an appropriation of £70,000 for a factory to produce sufficient powdered peat to supply all the locomotives on one of the State railway lines.—"Engineering News."

U.S. Coal Output.—According to estimates prepared by the United States Geological Survey, the output of bituminous coal in the United States in the first six months of the current year was the greatest ever recorded in any half-year period. The production during this period was 261,000,000 tons, an increase of 35 per cent. as compared with the production in the first six months of 1915, and greater by several million tons than the record output in the last half of 1913.

LIMIT GAUGES*

BY DR. R. T. GLAZEBROOK, F.R.S.

THE fundamental idea of limit gauging—that the dimensions of a piece of work should lie between certain definite values, and that the engineer should possess some means of measurement which would enable him readily to tell if this was the case—is probably quite old. Its importance, owing to the growth of repetition work, and the demand for interchangeability, has increased greatly of late; during the past two years the growth has been enormous. The work of the Engineering Standards Committee in this, as in many other branches of engineering industry, has been of the utmost value, and it is to the reports of that committee we turn for much of the information on the subject. It is impossible to speak on this subject without reference to the two men whom we have recently lost, whose labours did so much to promote the cause of standardisation. Sir H. F. Donaldson was chairman of the Committee on Gauges from its commencement. He threw himself into the work with all the energy of which he was capable; his tact and experience steered the committee over many shoals; his wide knowledge was of the greatest value, and his fairness and courtesy endeared him to all his colleagues. In all he did he was most ably supported by Mr. Leslie Robertson. Only the men who have been intimately acquainted with Mr. Robertson's work for the Standards Committee can realise the greatness of his loss, and the difficulty of finding one to fill his place.

Report No. 27, dated June, 1906, deals with British Standard Systems for Limit Gauges (Running Fits), and was the result of much careful enquiry and discussion. From it is taken the following definition:—

"*Limit gauges.*—Gauges for ensuring that any given dimension is within the tolerance laid down for the class of work to be produced. In the case of cylindrical work these gauges may be either double male gauges, one end of which must enter, and the other end of which must not enter the hole to which it is applied, or they may be either two-ring or two-gap gauges, one of which must pass over, and one other of which must not pass over the plug or male piece to which they are applied." And the report continues:—

"The committee have in view three classes of limit gauges, viz.:—

"(*a*) *Standard limit gauges* made in accordance with the recommendations contained in this report, and with the greatest possible accuracy, for depositing with the National Physical Laboratory, for purposes of reference.

"(*b*) *Reference limit gauges*, being copies of the foregoing standard limit gauges for use by manufacturers and others for checking their own shop gauges. They should be verified, and their accuracy certified by the authority in whose custody the standard limit gauges are deposited.

"(*c*) *Shop limit gauges.* The gauges actually used in the shop and checked against the reference limit gauges."

To this list it is desirable to add "check gauges," *i.e.*, gauges designed to check readily the dimensions of gauges in use either as reference gauges or as shop gauges. These are usually the inverse of the gauges they are employed to check, *i.e.*, for a hole the check gauge is a plug and vice versâ. I propose to say something about these various classes of gauges—their use, the permissible limits of accuracy, and the methods of measuring or otherwise determining their dimensions; but before proceeding to this three other terms in common use need definition. These are:—

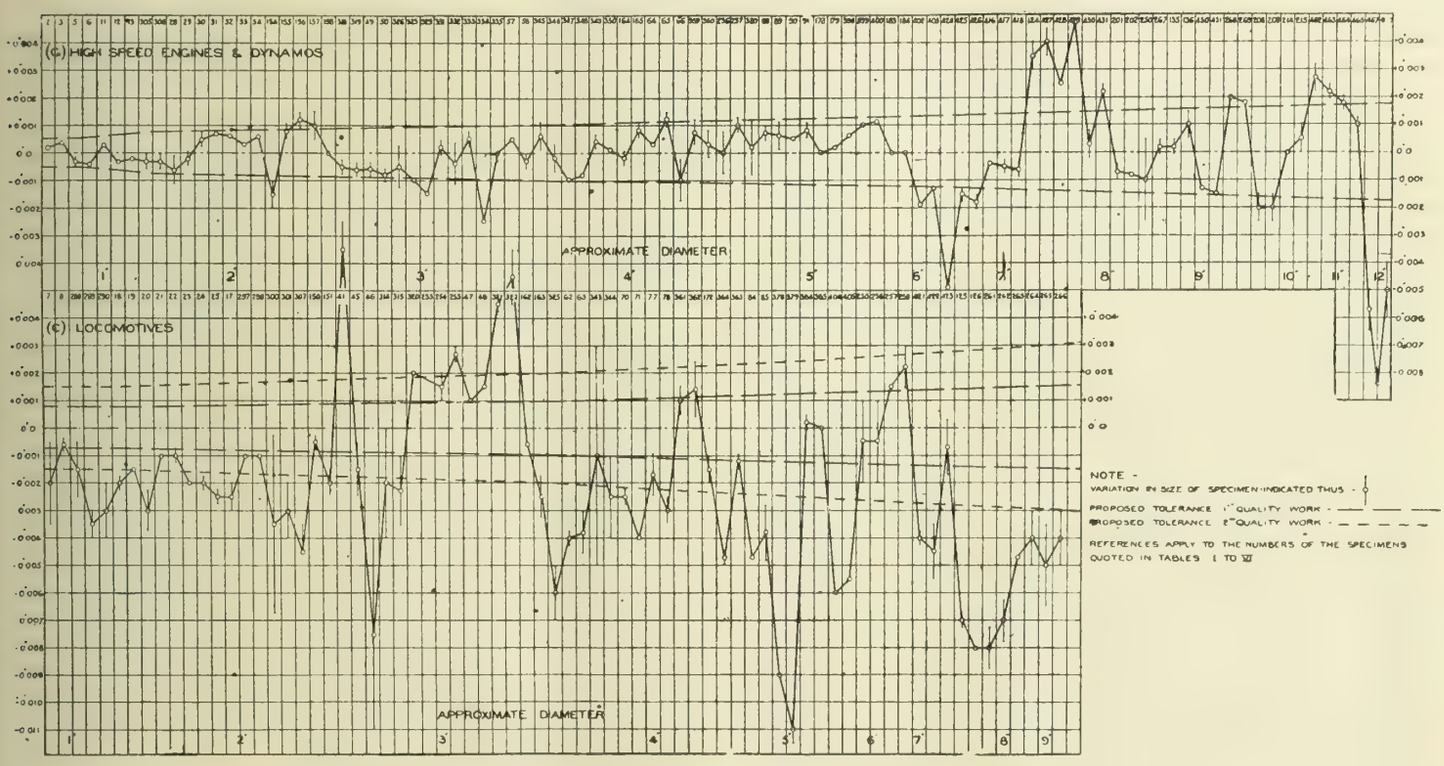


FIG. 1.—ERRORS IN WORKMANSHIP. SHAFTS, CLASSES G & C.

Tolerance.—A difference in dimensions prescribed in order to tolerate unavoidable imperfections of workmanship.

Allowance.—A difference of dimensions prescribed in order to allow of various qualities of fit.

Clearance.—A difference in dimension or in the shape of the surface prescribed in order that two surfaces or parts of surfaces may be clear of one another.

In dealing with gauges we may subdivide them usefully into three groups:—

(I.) Gauges for plain cylindrical work.
(II.) Screw gauges.
(III.) Form and position gauges.

Years ago Sir Joseph Whitworth embarked on the standardisation of certain gauges for plain and screwed surfaces, and the use of Whitworth gauges has been of enormous value to engineering science; but these gauges are not, and had not at the time the committee began its work, been used as limit gauges in the true sense; consequently interchangeability was not secured. Sir Joseph aimed at standards which should be true dimensions, and he made no effort—at that time it did not appear necessary—to specify plus or minus limits for each class of work. Accordingly, at the outset, the committee were faced with the necessity of enquiring what should be the limits on the work in order that interchangeability may be secured, and what gauges are required for this purpose.

I. Cylindrical Work and Gauges.—In dealing with the

* Paper read before Section G of the British Association, at Newcastle, September, 1916.

work it is clear that the tolerances and allowances must depend on its nature and the class of fit aimed at; different allowances are necessary for running fits, push fits, force fits, &c. In the year 1906 the data available to determine these were small. Accordingly arrangements were made by which Mr. Attwell, of the National Physical Laboratory, visited the workshops of many of the leading manufacturers of the country, and by their kindness carried out the accurate measurement of plain cylindrical shafts and holes from 2in. to 12in. diam. The results are contained in the tables and plates of a long report (No. 25), dated July, 1906. Figs. 1 and 2 are an illustration. Certain firms—notably Messrs. Armstrong, Whitworth—had already adopted a system of limits for their own use, and information on these was also before the committee.

As a result the committee were able to draw up a definite series of recommendations with regard to running fits, though, before reaching a final decision, another difficulty had to be faced. Are the dimensions of the shaft or of the hole to be made the basis of the work? With an inch shaft, for example, is the shaft to be made as nearly 1in. as possible, with only the necessary tolerance and the whole of the allowance, to secure the running fit to be made in the hole, which is therefore of necessity larger than 1in. by the amount of this allowance, or is the reverse course to be adopted? In the end the committee adopted the view that wherever possible the shaft should be the element more nearly approaching the true dimension, and allowance be made on the hole, according to the kind of fit required. The tolerances on the shaft are negative, so that it may never exceed its nominal dimensions. A minimum allowance obtained by making the hole of larger than nominal size is specified, and this cannot be encroached upon by either element; above this a positive tolerance is allowed on the hole. For example, in the case of a 5in. shaft and hole of first-class work, the tolerance on the shaft is ·002. Thus it must lie between 5·000in. and 4·998in. The allowance is also ·002, so that the minimum diameter of the hole is 5·002in. On this there is a tolerance of ·002 again, hence the hole may have a maximum diameter of 5·004in.

This system the committee call the shaft basis; they note, however, that the system may be reversed, the hole being taken as basis and the allowances applied to the shaft, the minimum diameter of the hole being its nominal size. The results of this part of the committee's work are shown in Fig. 3. It will be noted that, with a view to reducing the number of gauges required, the scheme has been arranged so that the maximum diameter of the hole for first-class work is the minimum for second-class work, and so on. Assuming now agreement has been reached as to the allowances and tolerances on the work, what as to the gauges? For a shaft we require two gauges—two rings or snap gauges, as may be preferred—one corresponding to the maximum or high dimension, the other to the minimum or low dimension, and, as perfect workmanship is impossible, these gauges must be subject to tolerances; what is to be said as to the sign and amount of the tolerances? And here a distinction has to be noted. So long as the work is within the limits allowed, interchangeability is secured, and it will pass inspection. In fairness, however, to the manufacturer, all work up to the limits should pass; the inspection gauges should not demand narrower limits than the production drawings. Accordingly the tolerances on a high inspection gauge must be positive, those on a low inspection gauge negative. This is a point which the gauge maker should carefully attend to. He knows maybe that the nominal size of a certain high gauge is 2·000in., with a tolerance of 0·0005in.; he should try then to make his gauge 2·00025in. In many cases the attempt is made to produce the gauges as nearly as possible 2·000in., and some are made a trifle too small; they are rejected necessarily; had their aim been to arrive at 2·00025in. probably all would have got through when tested.

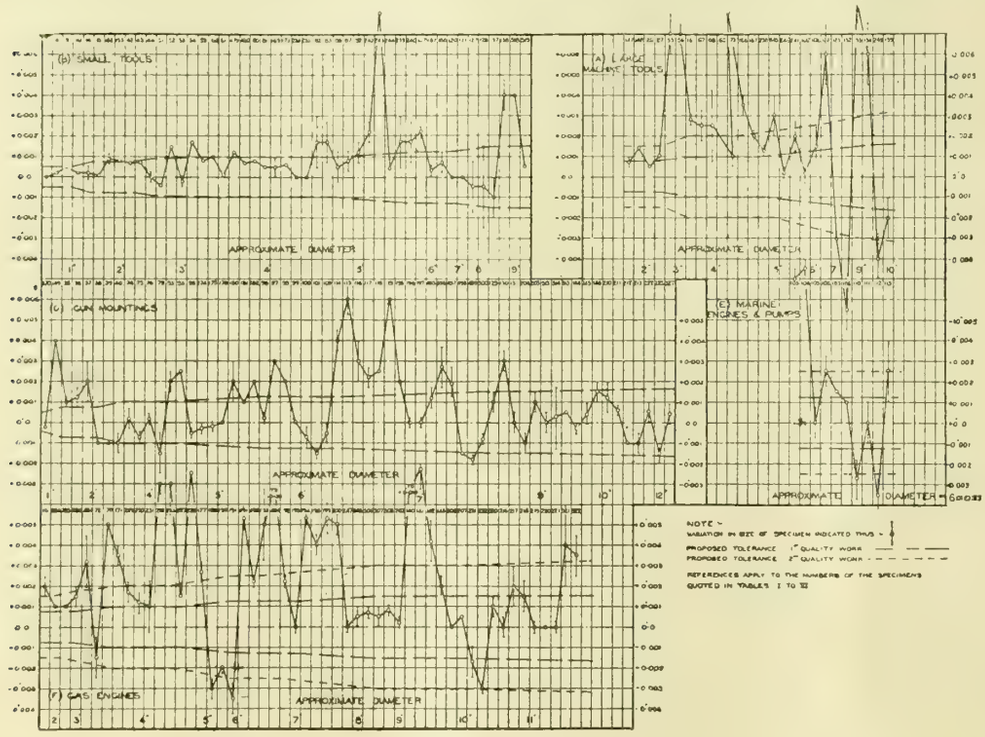


FIG. 2.—ERRORS IN WORKMANSHIP. HOLES, CLASSES A, B, D, E, & F.

So far, then, we have found that for an inspection gauge the tolerance is positive on the high gauge, negative on the low. But in the workshop gauge, as will be seen, the reverse is the case. These are given out by the manufacturer to the workman to enable him to make work which will pass the inspector. Clearly then, for safety he will arrange that the limits to which the man works are rather narrower than those to which the work will be inspected. A high gauge will be a trifle too small, a low gauge slightly too large; the tolerance on the high gauge is negative, that on the low gauge is positive. As to the tolerances permissible, these depend on the class of work dealt with, and for inspection gauges amounts of the order of one-tenth of the tolerances on the work are not unusual. Thus, for the 5in. shaft of first-class work already referred to, the high gauge would lie between 5·000in. and 5·0002in., the low gauge between 4·998in. and 4·9978in. These, of course, are close limits. For a workshop gauge the tolerances, as well as being of opposite sign, may wisely be large in amount; the result of this is to contract somewhat the limits within which the workman has to work, but to increase the chance that this work will pass. Moreover, the "go" gauges wear, and a ring or a plug may easily in time become too large or too small respectively if when new they are very close to their nominal sizes.

In our original classification of gauges, reference gauges were mentioned. These clearly include both reference inspection gauges and reference shop gauges; they are retained for the purpose of standardising the other gauges. We turn now to the measurement and testing of cylindrical gauges. For the purpose of merely testing a gauge to see if it is correct, two check gauges—a "go" and a "not go"—may be used, and in some cases must be used. The difference between these will be equal to the tolerance on the gauge they are used to check, and their own tolerances will be much smaller, but for cylindrical gauges in most cases check gauges are not necessary, and indeed are not desirable; the difficulties arising from inaccuracy of manufacture and wear are too serious. Besides, rejection by a check gauge gives no intimation of the error to the manufacturer, and thus it is unsatisfactory to him. Thus cylindrical plug gauges are preferably checked by some form of accurate micrometer or measuring machine. To describe such machines in detail would fill a paper by itself; it must suffice to mention one or two leading points.

The original Whitworth form depends on the use of a feeler, a bar which is passed down between the jaw of the machine and the gauge under test, and while high accuracy can be attained by practice the results are slow and depend on the skill of the observer. In another form the plunger presses against a spring and tilts a delicate level. The micrometer is turned until the bubble is central, thus securing that the pressure applied to the gauge is always the same; the importance of this is very great. It has been found useful at the National Physical Laboratory to replace the level by a tilting mirror; the machine is in adjustment when a ray of light reflected from the mirror occupies a definite position of a suitably placed scale. This device is used on a large machine built to the Laboratory design by Messrs. Armstrong, Whitworth. It is employed to measure large cylindrical gauges, and was built for the measurement of the coils of some of the standard electrical apparatus. Another instrument in regular use for testing smaller cylindrical gauges comprises a vertical

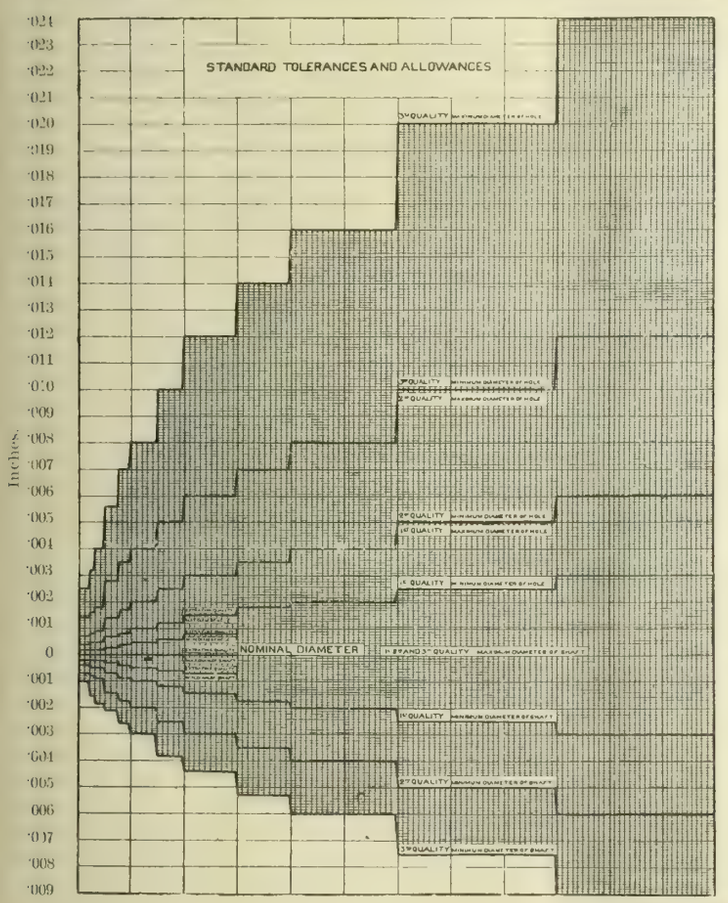


FIG. 3.

plunger pressed downwards by a spring which actuates a light lever moving over a scale; below is a horizontal platform with a slow vertical motion. A standard gauge of the required dimension is placed on the platform which is raised until the upper end of the gauge pressing on the plunger brings the lever to the centre of the scale; the standard is then removed and its place taken by the gauge under test. The difference between this and the standard is given by the position of the pointer on the scale. In another instrument of this class the motion of a diaphragm raises or depresses a column of liquid in a fine tube. All these methods demand the employment of accurate standards of a large variety of lengths. Such are afforded by the now well-known Johanssen gauges. By means of these length gauges differing in length by one or more thousandths of an inch can be built up with an accuracy amply sufficient for checking gauges to under the one ten-thousandths, and most of the test work at the National Physical Laboratory is now done by the aid of these gauges. To discuss the problem how the Johanssen gauges are checked would carry us too far into detailed consideration of such work, while how to make them is a secret many would wish to share with Mr. Johanssen.

The checking of ring gauges or of snap gauges is a more difficult problem. For many purposes check gauges are used—a "go" and "not go" plug, the external diameters of which can be accurately measured, and, indeed, for small rings this is the only method. For larger gauges there are various forms of internal callipers available, but these do not lend themselves readily to high accuracy. A method which has been found convenient at the Laboratory is to build up a "go" and "not go" internal diameter gauge by means of a series of Johanssen gauges with two plain cylinders of known diameter, one at each end of the series. When once such a diameter gauge has been put together, the checking of a series of rings of the same diameter becomes a simple matter.

(To be continued.)

MIKADO TYPE LOCOMOTIVES.

WE have received from the Baldwin Locomotive Works, Philadelphia, an interesting booklet describing and illustrating the various designs of locomotives made by them and designated as the "Mikado" type.

The first locomotives of this type were built by the firm in 1897, for the Nippon Railway of Japan, and embodied, in their design, the most advantageous feature of the type, viz.: a wide, deep firebox combined with the 2—8—2 wheel arrangement. In 1902, a locomotive of similar type was built for the Bismarck, Washburn, and Great Falls Railway in the United States; and since that time large numbers of these locomotives have been constructed for heavy freight, and also, to a limited extent, for mountain passenger service.

The success of the Mikado type is due chiefly to the large steaming capacity provided in proportion to adhesion. As usually built, the boiler has a long barrel and a deep, wide firebox, which is placed behind the driving wheels and over the trailing truck, so that the driving wheels are not overloaded thereby. In locomotives of the Consolidation (2—8—0) type, the firebox is usually placed above the rear pair of driving wheels, and the boiler is necessarily of smaller dimensions than in a Mikado type of equivalent tractive force. With equal weights on driving wheels and equal ratios of adhesion, a Mikado type locomotive, it is said, shows no superiority over a Consolidation at starting, but as the speed increases, the tractive force falls off less rapidly, because of the greater boiler power of the Mikado. This is illustrated by a diagram, which shows the percentage of the starting tractive force developed at speeds up to 60 miles per hour, by representative Consolidation and Mikado type locomotives. At a speed of 30 miles per hour the Mikado type develops 50 per cent. of its maximum tractive force, as compared with 35 per cent. for the Consolidation. The curves represent average conditions, and are based on the assumption that the boilers of both locomotives are being worked at their maximum evaporative capacities. The fact that Mikado type locomotives can maintain high tractive force at increased speeds, fits them not only for heavy freight service, but also for fast freight service, and for passenger service on mountain grades.

With space available for large grate area and furnace volume, the locomotives can readily be designed to use low-grade coal.

The wheel arrangement is specially suitable for service in which frequent backing is necessary. The rear truck under such circumstances protects the driving wheels against flange wear, and guides the locomotive into sharp curves and switches without danger of derailment.

The majority of this type of locomotive recently built are equipped with superheaters, and under favourable conditions an economy of 25 per cent. is claimed in the coal consumed per unit of power developed, as compared with locomotives in similar service using saturated steam.

The operation of large Mikado locomotives is considerably facilitated by the use of such labour-saving devices as power-operated fire doors, grate shakers, and reverse gears. Mechanical stokers are, it is said, also being used to a limited extent. These stokers have now been developed into practical devices and by their use large locomotives can be worked at full capacity, under conditions where it would be impossible to maintain steam pressure with hand firing.

THE SALES ENGINEER AND HIS INFLUENCE ON MACHINE TOOL DESIGN.*

BY A. J. BAKER.

THE title engineer has already been subjected to so many prefixes that one hesitates to add another to the already confusing number. There seems, however, hardly any other term than that of sales engineer which quite so well defines the activities of that growing class of engineers with whose influence on design and production it is proposed to deal in this paper.

It is, of course, no new thing for the larger engineering institutions, notably electrical, hydraulic, railroad, &c., to bring their engineers directly into, and to keep them in touch with the problems that they have to solve. This is accomplished through personal visits to the locality of the proposed installation and investigations of the natural conditions that have to be overcome. It is even obvious that no thoroughly satisfactory results could be expected unless such research were made, and in the industries mentioned, such action is considered entirely standard and customary. It is not the writer's intention to touch on such fields of activity, but rather to confine his observations to the application of the same principle to the machine tool industry.

As one views the progress of machine tool design, one cannot help but feel that it has been largely left to the user of a machine to indicate the changes which made the machine more particularly suitable for his class of work, and that the designer and maker of the machine has generally been the second party in such improvements. I do not refer to detailed improvements particularly in regard to the construction of the machine, but rather to those marked departures from type, that may be said to mark the advances in the art. In other words, it would appear that the majority of the engineer-designers of most machine tool factories have for many years been working on improvements of well-defined types of machines and cannot have made that rigid investigation of the conditions which govern the use of such machines that would seem to be absolutely essential if ideal conditions are aimed at.

There are very strong commercial reasons from the manufacturer's standpoint for standardising the design of machine tools. From the user's viewpoint there is the further excellent reason that relates to the ability of the average operator to handle with the minimum amount of individual instruction, any machine of the class in which he claims proficiency. Probably in the last analysis this would also be regarded as a commercial reason, but it must also be taken into account in view of the apparent tendency toward the increased employment of unskilled help and the comparative difficulty of obtaining that rare individual commonly known as an all-round machinist.

This tendency to standardise on types of machines is again a very logical outcome of the development of most machine tool factories, which will be found to have grown up from a small organisation breaking away from a parent company and devoting its energies to that one particular machine of which the new organisation had a very definite knowledge. The growth of the new concern, as a rule, demanded the close attention of all the responsible parties toward solving the immediate problems. The tendency was to limit the activities of the engineers to individual parts of the machines and not to encourage attempts to produce variations of machines suitable to the special requirements of each individual customer. To-day we are vitally concerned with a somewhat different problem. The user of a machine tool has been educated to demand of the machine tool manufacturer a specific study of his requirements. These studies have, and will more markedly in the future, influence the design of the manufacturer's product. The service plan, in vogue in many trades, has become a part of machinery organisation.

This condition has led to what I term the sales engineer. His predecessor was the original demonstrator, who, it will be remembered, was and still is a man unusually skilled in the use of the machine which he demonstrates and who is sent out to break in the workmen and to assist the customer in obtaining high production from the newly installed tool. These demonstrators in their visits to the different plants accumulated considerable experience in regard to the uses and weaknesses of their machines. They provided a highly valuable intermediary between customer and manufacturer, and following the natural onward tendency, they were in some cases replaced or augmented by engineers, whose duties were not in any way connected with the demonstration or practical operation of the machine. They observed the uses to which the machine was put. These observing engineers carrying back to the factory their authentic data, were able to materially influence new designs. They were still, however, concerned only with the standard type of machine and were only brought into contact with the customers' requirements after the machine was installed, and usually when some trouble had developed with the installation. The next step was in the utilisation of these engineers in conjunction with salesmen, or agents, to investigate the customer's conditions before recommendation was made as to the installation of machines. You will note that his function was not to sell the machine; in fact, it was his duty to prevent the sale of machines where his knowledge made it evident that the customer's best interests would be so served. It became necessary, therefore, particularly as the mechanical responsibility of the whole transaction developed upon him, to make a reasonably thorough analysis of the problem before proceeding with any recommendations. This analysis, in many cases, leads directly towards the design of new machines of possibly the same general classification, but of an entirely different type, and I propose to mention here a few of the causes that bring this about in much greater measure than when the older method of machine design was followed.

The original machine designer usually devoted himself so closely to his own particular machine, that he was not thoroughly in touch with developments taking place on other classes of machines. Even to-day, in the great majority of cases, that condition prevails. The sales engineer, on the contrary, being brought directly and frequently in touch with the last installations of such machines, immediately returns to the factory with advance information of the encroachments that the new type of machine is making on his own field. The designing department, lacking a detailed acquaintance with the last usage to which machines are put, loses its proper perspective in regard to the relative time values of the different functions of the machine. The sales engineer, with any reasonably well developed analytical faculty, can clearly see that a certain portion of the operation consumes more time than is really necessary, that the output is governed by this factor, and advises the home engineer of the need for improvement in this respect. The home engineer includes in each new machine or each new design certain parts, which, while necessary, or at least desirable, under the old system of comparatively low production, are not only unnecessary with the present high production ratio, but are absolutely undesirable on account of the added complication which their presence entails. The sales engineer, being brought face to face, as he must often be, with the relative selling prices of machine tools, will naturally tend towards an elimination of those less desirable features with a consequent simplification of the machine. His more continuous travels throughout the various shops must of necessity bring him into close contact with many home-made devices, which are often the basis of permanent improvements in standard design. It is idle to suppose for a moment that such improvements are found only in the larger shops, to which as a rule the visits of the home engineer are confined. More often it will be found that the small shop with its restricted equipment will have produced some interesting and instructive method of producing the desired results, where the larger and wealthier shop has been content to increase its quota of standard machines.

Carefully tabulated records of similar jobs performed in different shops will nearly always indicate parts which may be omitted and functions that should be added, which information cannot be obtained in any other way with either the same certainty or speed, and in these ways the influence of the sales engineer on the design of his company's product cannot fail to be very marked. His influence on production, while closely connected with design and thus of interest to the manufacturer, will be of more vital and material interest to the customer. The general adoption of this sales engineering system immediately places at the disposal of the machine user a corps of highly trained engineers whose collective abilities

* Abstract of paper read at a meeting of the Cincinnati section of the American Society of Mechanical Engineers.

are likely to greatly exceed those over which he would normally have control. Their advice and recommendations should, and often do, lead to the scientific selection and installation of machines, which, while representing a lessened installation outlay, will give much greater production than if the older system of machine purchase were followed.

It must be apparent that the recommendations of the sales engineer cannot be made on the spur of the moment, but must receive a reasonably thorough preliminary study and investigation. In one company it has been the practice for the last half-dozen years to make comparatively elaborate time studies, for which considerable advance information is needed. This information must not only cover the end which it is desired to accomplish, but should also include a reasonable amount of data as to the earlier and existing methods. This is particularly essential because it has developed that the sales engineer, seeking continual outlet for his machines, will often invade the field that has been considered the exclusive property of some other type of machine. It is sufficiently obvious that there must be much debatable ground to be fought over by the competitive representatives of the engine lathe, the turret lathe, and the automatic machine, and again between the planer, shaper, and miller. The ideal conclusions drawn from such investigations can only follow a very full consideration of all of the factors connected with production, and not alone, as is sometimes the case, with the number of pieces turned out per machine per day.

For these reasons certain standard forms are used on which is entered the following information, derived from the user of the machine: (1) The quantity per annum and, if possible, the size of the lots in which the work is put through the factory. (2) The degree of finish required. (3) The quality of material. (4) The depth of cut. (5) The machine on which the work is now being done. (6) The time consumed. (7) The wage rate paid. (8) The burden or overhead charge, particularly if departmental burden is available. (9) And the objections, if any, other than as to the time consumed, that may be made to the existing method. This latter may deal with the labour supply, the dependence upon certain materials, or certain other limiting conditions.

This report is supplemented either by a sketch of the piece, or preferably by the customer's blue prints. Samples for preliminary cutting tests are also obtained whenever possible. With all of this information, a time study can be made up, which will give in full detail the separate operations, the time taken for each part of the operation, the speed and feed necessary, and a sketch and description of the fixture and cutters to be used. The resulting total time, which will then represent the time required for the production of the individual piece, receives the addition of a certain percentage, which will vary with the nature of the shop, and is a figure that can be easily established as a standard. This information is then submitted to the customer and in certain cases accompanied by a cost sheet, comparing the suggested and existing methods. This sheet will specify the time per piece, including the above percentage; the total time per annum for the quantity of pieces required; the wage cost; and the burden or overhead cost showing an annual saving over the old-established system. This saving may be balanced against the increased cost of equipment as contemplated by the customer. Such cost-comparison and estimate sheets are in themselves not necessarily final, but their great virtue is that they form a nucleus for specific analysis and recommendations, on the part of the customer and his engineers. It is particularly important that such detailed information should be submitted, because the production from a given machine is very often entirely independent of the ability of that machine to carry through a certain cut. It is often entirely dependent upon the chucking time afforded the operator, and still again frequently it depends upon the spacing of the feed marks, or quality of finish. This latter may very well be a commercial necessity and entirely independent of the degree of accuracy.

We can assume that the time study shows conclusively how the major proportion of the operation still is dependent upon the operator's chucking capacity. There are two ways in which this may be increased, either by the elimination of certain functions he must perform in connection with the machine, or by so changing and improving the holding arrangements for the work as to reduce the chucking time proper. In a great many cases the former situation is the one that develops, since it is only reasonable to suppose that the fixture or work-holding device, having been made especially for the job, shall represent a higher degree of efficiency than can be found in a machine which has been designed for more general purposes. It is here that the twofold influence of the sales engineer on both design and production becomes pronounced. It is brought home to him very strongly that the specific limitation of his machine, while originally of small importance, is preventing a greater output. It must then suggest itself to him that some mechanical means must be found for overcoming the hand operation of the machine and either of his own volition, or through the home engineering department, he will produce modifications of the machine to suit requirements.

A further important point in this connection is the influence that would be brought to bear by the customer himself. His viewpoint of the machine must necessarily be different from that of the manufacturer, since he is not in the slightest degree concerned with the details of its construction. It is almost impossible for the manufacturer himself to take that view, since on the careful watching of those details must depend much of his success. The user will more often clear his mind of all the details of the machine and reach the pertinent points that are connected with production. He is more apt to compare the machine the sales engineer may be interested in with some other entirely different machine, which incorporates some feature of marked importance to his particular class of work. It would seem, for instance, that the day of the automatic-power return of the tables of small milling machines would have come much sooner had its users compared the miller with the planer in the way that should have been done. It would really not have been necessary to compare the miller with the planer, but to have compared it even with some of the larger planer type milling machines, on which such apparatus is standard equipment. It would further seem that the flooded lubrication of milling cutters should have come sooner had the proper comparisons been made between a milling machine and a grinder, and parallel cases could doubtless be found throughout the full machine-tool field. The customer, as a rule, either has not the time, or he perhaps lacks the energy to bring such points strongly enough to the attention of the manufacturer, and it is to be hoped that through the efforts of the sales engineer more concerted action between user and maker will accrue.

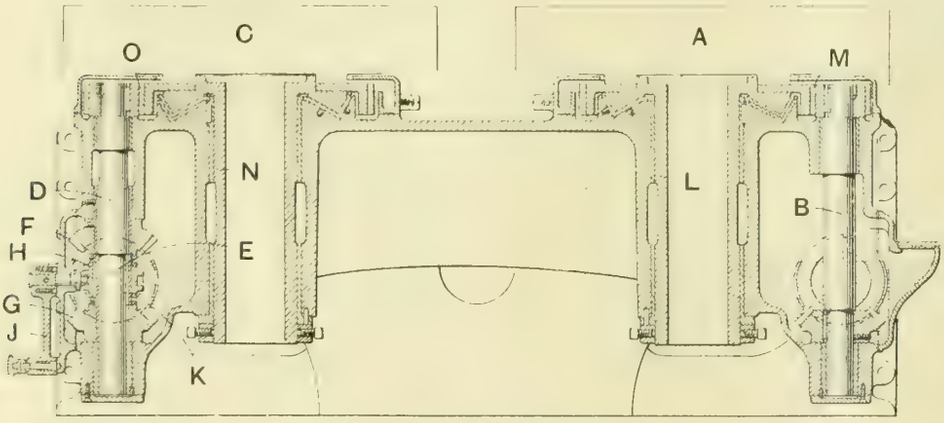
There is another phase of the sales engineer's influence on production, and that is concerned with the work-holding methods or fixtures. There are in many shops ingenious methods in force for achieving a desired end, which methods may be very well adapted, not necessarily to the same specific job, but to others of a similar nature. Now these methods must come fully under the eye of the sales engineer, not only in his visits to the customer's shop, but in his comparison of the suggested with the existing method. This interchange will be more far-reaching in its influence than if the comparison between methods and production were always limited to one type of machine, since, as is well known, the different types of machines have each tended to develop a different system of standards of holding appliances

The foregoing roughly outlines the direction in which the sales engineer may be expected to influence production and design. More striking evidence of the growth of this particular field of activity is to be found in the changing personnel of agencies. Some machine-tool concerns are represented by agents who are by virtue of their limited individual territories brought more closely into contact with the customer than the sales engineer can hope to be. It needs but little reflection to see that the change in the make-up of the machinery salesmen or agencies has been very marked and that their ability to render practical service to the consumer is much greater than ever before. Some of the agencies with which the writer is acquainted are controlled by men of marked mechanical attainments. Their influence on production is very great indeed, and in certain cases they have contributed considerably to the creation of new designs. It is probable that the full record of the influence of the separated selling houses on machine-tool design would make highly interesting and instructive reading.

There must result for all of us some distinct benefit from a full and careful interchange of ideas, and it seems that this can hardly be made with much more certainty and satisfaction than when the medium is one who must demonstrate the efficiency of that machine in which he is vitally interested, or failing such demonstration must make changes in the product to meet the conditions found.

IMPROVEMENTS IN DUPLEX BORING AND TURNING MILLS.

MESSRS. WEBSTER & BENNETT, LTD., Northey Road Works, Foleshill, Coventry, in conjunction with Mr. H. Thompson, have recently introduced and patented some improvements in duplex boring and turning mills. In the majority of these tools the tables are arranged close together with the control mechanism at the extreme ends of the mill. It is naturally desirable that the cutting tool be located on the side of the work next the control mechanism so that the operator can watch the operation, but it is also very important that the tangential component of pressure on the cutting tool be in a direction towards the cross slide. This means that for turning work the tables should revolve in opposite directions. This in most cases necessitates two sets of boring and reamering tools with oppositely directed cutting edges. The arrangement illustrated has been designed with a view to avoid this necessity. The right-hand table A, which is mounted upon the spindle L, is driven from a lay shaft B through a constant pair of gears at M, so that it rotates always in a direction which is counter-clockwise looked at from above. The operator stands at the right-hand side of the machine, and the control mechanism, which is not shown, is at the right of the axis of the spindle L and therefore the control mechanism is handy. The left-hand table C, which is carried on the



DUPLEX BORING AND TURNING MILL.

spindle N, is also driven from a lay shaft D through constant gears O. The lay shaft, however, can be driven in either direction from a constantly-running shaft which is in geared connection with the feed mechanism. The axis of this shaft is shown at E and as it always runs in the same direction the feed mechanism is not reversed when the direction of rotation of the table C is altered. On the lay shaft are two bevel gears F and G, either of which can be clutched to the lay shaft by sliding a dog clutch member H under the control of a lever J. The two gears F and G mesh with a bevel wheel K on the driving shaft E. Thus by engaging the clutch H with the correct gear F or G the table can be caused to revolve in the required direction. For boring, reamering, or similar operations it revolves in an anti-clockwise direction, and the same type of boring tools can be used for both tables. For turning work the table C is rotated in the opposite direction so that special turning tools are required for the left-hand table, but considerable advantages are obtained because the tangential cutting pressure is more efficiently taken by the cross slide. The control mechanism for the left-hand portion of the mill is arranged at the left-hand side of the axis of the table C.

STANDARDISATION AND ITS ASSISTANCE TO THE ENGINEERING INDUSTRIES.*

Introduction.—This paper has been prepared at the request of Prof. Howe, who informed the secretary of the Engineering Standards Committee that the Organising Committee of the British Association had decided to invite the presentation of a limited number of papers on subjects of national importance.

General Views on Standardisation. In regard to standardisation as applied to engineering practice, much has been written, and it has, in fact, become so necessary to progress and is, indeed, so familiar to most of you that it will suffice on such an occasion as this to draw attention to a few of the more important aspects of the subject and at the same time place on record something of the success which has been achieved in this country of late through the effective co-ordination of individual effort.

It is scarcely necessary nowadays to insist on standardisation as being of paramount importance to economic production, but that was not so clearly seen 16 years ago, before the advent of the British Engineering Standards Committee. However, keen competition from outside, the legitimate demands of labour for a higher standard of living, coupled with the desire of capital for an adequate return, have compelled the whole industry to introduce modern order and system in all its methods of production, former individualistic methods giving way to co-ordination and collective effort. These improvements, which have already resulted in marked benefits, must not only be maintained, however, but continually added to if the full advantages are to be reaped.

The individual gain in private workshop standardisation is acknowledgedly great to the producer, for it tends towards interchangeability of component parts, facilitates quick delivery, and reduces maintenance charges and stores. In these ways it benefits also the consumer and the nation at large.

Crystallisation, however, which would tend to impede and to stultify progress, must be jealously guarded against if standardisation is to be of permanent value and the purchaser is not to be deprived of the benefit of competitive effort and inventive genius. Those responsible for the initiation of the standardisation movement in Great Britain realised from the first that in order to avoid undesirable stereotyping of practice it would be necessary from time to time to revise standards, and this has become recognised as an essential part of any standardisation work, which never can be regarded as final. In this way the community of interest of buyer and seller was, and is, realised through the acceptance by both of an agreed yet flexible standard.

Satisfactory results have been arrived at not by one section of the community imposing its opinions on the other, but rather as the result of co-operative action, mutual concession, and ultimate agreement between all the interests concerned. The adoption of standards agreed on in this way undoubtedly promotes uniformity of practice, avoidance of waste, elimination of harsh and unnecessary conditions, reduction of manufacturing costs, and last, but by no means least, engenders a feeling of mutual confidence between user and producer such as could not be secured by isolated action on the part of either.

Experience, moreover, has shown clearly that such procedure does not lower the standard of quality, but tends rather to raise it, for standardisation carried out along these lines reflects, in effect, the consensus of opinion as to what constitutes best modern practice.

Successful standardisation can only be arrived at by common consent of all those who take full part in the initiation and working out of the actual details of the various specifications which are intended to be recommended ultimately for public use. The realisation of this guiding principle by the founders of the Engineering Standards Committee is probably one of the chief reasons for the wide adoption of the British Standard Specifications, which have no authority other than that of public opinion.

The Committee, its Inception and Growth.—The movement, as represented by the Engineering Standards Committee, the greatest voluntary effort of its kind, in which public spirit has been so lavishly shown, was founded in 1901, through the initiative of Sir John Wolfe Barry, K.C.B., who had long been coming to the conclusion that some means were urgently required to systematise design and production of component parts.

In 1897 certain remarks made by the late Lord Salisbury on the desirability of scientific physical standards and constants to an important scientific deputation, which resulted

* Paper read before Section "G" of the British Association, at Newcastle, September, 1916 by the Secretary of the Engineering Standards Committee.

shortly afterwards in the establishment of the National Physical Laboratory, confirmed Sir John Wolfe Barry in his opinion, and in January, 1901, he laid the matter as affecting the engineering trades of the country before the Council of the Institution of Civil Engineers, with the result that a Committee was appointed to consider the question of standardising various kinds of iron and steel sections. The Committee reported favourably on the project, and the Council of the Institution of Civil Engineers adopted the report, and the co-operation of the five leading engineering institutions of the kingdom, viz., the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, the Institution of Electrical Engineers, was subsequently secured. The original reference to the Committee was enlarged by resolution of all the Councils of the supporting institutions, and full power was conferred on the Committee as to publication and the best manner of giving effect to their findings.

Thus from a single Committee, consisting originally of seven members, appointed to discuss the advisability of standardising rolled sections and rails, has grown the present far-reaching organisation with its 64 committees and sub-committees, as well as numerous panels, including, in all, well over 500 members freely giving their time and experience, often at great personal inconvenience, and dealing with subjects embracing practically the whole of engineering practice. It is due to the memory of the late secretary, Mr. Leslie Robertson, to say that the success of the Committee has been largely owing to his energy, foresight, and conspicuous ability. His intimate knowledge of men and affairs, combined with sympathetic consideration for the views of all, enabled him to cope successfully with problems which otherwise would have presented more serious difficulties.

The internal organisation of the Engineering Standards Committee need only be very briefly referred to, as it is fully set out in the Report on Work Accomplished, which is issued annually. The Main Committee, which is composed of 19 official representatives of the five leading engineering institutions, has charge of the administration of the whole of the work, the raising of the necessary funds, the controlling of the expenditure, the selection of subjects for standardisation, and the ratification of all reports and specifications presented by the various sectional committees for its approval prior to publication. The sectional committees are appointed by the Main Committee, who nominate the respective chairmen and arrange the mode in which the subjects are to be dealt with. The sectional and sub-committees contain representatives of the various Government departments, consulting engineers, manufacturers, contractors, and users, as well as representatives from the technical societies and trade associations concerned.

The Main Committee only studies subjects at the request of the various sections of the industry concerned, and does not venture to make recommendations except on the initiative of the engineers or responsible representatives of the trade affected.

The utmost care is taken at the very outset to ensure that all who have or could possibly have any interest in the proposed standardisation shall be adequately represented (through their recognised societies and trade associations if such exist) on the committee entrusted with the work. If necessary, evidence is taken, the advice of experts is sought, and in this way all parties are consulted and have a voice in the initial proposals, thus avoiding much subsequent friction which might otherwise occur.

In drawing up industrial standards, experimental investigations frequently become necessary in order to establish the facts underlying the principles involved, and in this connection the National Physical Laboratory has been and is conspicuously useful. It is in effect the Committee's official testing bureau, and its ultimate authority in matters concerning electrical and mechanical tests, acting in an advisory capacity in all the work in which unbiased experimental data are essential.

Each sectional committee is given an opportunity, once a year, of passing in review the specifications for which it has been responsible, for possible revision or addition if experience shows that such is desirable, and it is this system of keeping abreast of invention and progress which adds so greatly to the practical value of the work of the Committee.

The British Standard Specifications, which are confined to the main technical clauses necessary for the purchase of the product to which the specification relates, find an increasingly wide adoption. They are being increasingly adopted throughout the country, in home and export trade in general, and are also being largely substituted for the various and differing Government and municipal specifications formerly employed. They are proving of increasing value to the Crown Agents for the Colonies and the self-governing Dominions, and are, in large numbers, being sent abroad for use in the supply of engineering material required.

Success of the Movement. As already mentioned, one of the first objects in the formation of the Committee was to simplify the rolling of steel sections for engineering structures and rails as well as shipbuilding material so as to save unnecessary cutting of a variety of rolls for no good reason and also to facilitate the making to stock during slack times. That the work of the Committee in this direction has been amply rewarded is shown by the fact that the number of rolls in use by British manufacturers has been largely reduced. As an instance, whereas there were formerly 70 sections of tramway rails, there are now only five. The same is true of all ordinary merchantable sections such as angles, tees, and channels and rolled joists. The percentage of British standard tramway rails to the total tonnage rolled during the year ended March, 1915, was 75 per cent., which is an indication that the number of standards recommended is adequate to meet all ordinary requirements. A considerable reduction has similarly been effected in regard to railway rails, and the work of the Committee is evidently of material benefit to the railway companies by the wide adoption of its findings and the substantial manner in which they financially support the Committee's activities.

Turning to the case of Portland cement, the British standard is now generally adopted by engineers and manufacturers throughout the whole country, and the large number of copies of the specification which have been sold, 3,500 copies since the 1910 revision, goes to show its general utility to the industry. For 1913, the output of Portland cement of the country was over 3,000,000 tons, 95 per cent. of which, it is estimated, was made to British standard.

The London County Council, in its General Powers Act, 1909 (Part 4), amending the London Building Acts so as to provide for the construction of steel frame buildings, has required that all rolled steel used in the construction of skeleton frameworks of buildings shall comply with the British Standard Specification for structural steel for bridges and general building construction, and that all brickwork, concrete, stone, and other similar materials used in conjunction with the metal frameworks shall be executed in cement conforming with the British Standard Specification for Portland cement.

It is estimated that 60 per cent. of the material used in the manufacture of railway rolling stock in Great Britain is made to British standard. It would also appear from returns that for five of the largest steel works during 1913-14 the British standard sections totalled 95 per cent. of their output. The sections recommended by the Committee for structural steel may be had from practically all the steel works in the country.

The Admiralty has adopted the British Standard Specification for steel for marine boilers, where steel of the tensile strength dealt with therein is required, the British Standard Specification for structural steel for shipbuilding, and subject to certain additional requirements made necessary by the special character of naval work, the British Standard Specifications for steel castings and forgings for marine purposes. The Admiralty has also decided to adopt the British standard fine threads (Report No. 20) for all bolts, nuts, and studs for marine work generally, and the War Office has specified them in many cases. The War Office has also adopted the British standard rim diameters for solid tyres (Report No. 71).

The Board of Trade rules for the survey of passenger steamships are in accordance with the British Standard Specifications for boiler steel, ingot-steel forgings, and steel castings. Lloyd's Register has adopted the British standard sections, and the standard specifications for steel for shipbuilding and marine boilers and for steel castings and forgings for marine purposes, and has incorporated these in its rules. The British Corporation for the Survey and Registry of

Shipping, and the Bureau Veritas have likewise given effect to the Committee's recommendations in their rules.

The Admiralty has, moreover, taken the keenest interest in the electrical work and, in nearly all cases, has adopted the electrical specifications of the Committee, except where the exigencies of the service required departures owing to the special conditions which have to be met at sea.

The Indian Government and Indian Government Railway Companies, besides adopting the specifications of the Committee for manufactured work, requested in 1903 that the standardisation of types of locomotives be undertaken by the Committee and, in all, six broad-gauge and four metre-gauge engines have been standardised, and at the further request of the Indian Government designs for three more standard engines are in preparation. Since the issue of the first report in 1905 more than 1,600 standard broad-gauge and 700 standard metre-gauge engines, representing roughly about 7½ millions sterling, have been built for India. Criticisms have sometimes been heard in regard to this policy of the Railway Board of India, but over 10 years of practical experience has evidently demonstrated the wisdom and economy of this policy, which might, with advantage, be followed by our home railways. Crystallisation of design and stagnation has clearly been avoided by the policy of a standing committee reviewing its recommendations at stated periods and adopting modifications as and when deemed necessary. Evidently the requirements of the locomotive engineers of the Indian railways are being met satisfactorily by the comparatively small number of standard types recommended.

The Home Office, in a memorandum on chains and lifting devices, notes the increased use of the two higher grades of wrought iron recommended by the Committee, and encourages their general adoption by chain makers. Also, in a recent Order in Council, the Home Office requires that the wattage of tungsten filament lamps used for automobiles shall be limited to the maxima given in the Committee's report dealing with that subject.

Much work has been carried out for the Road Board in regard to sizes of broken stone for roadmaking, and these recommendations, having been adopted, will doubtless be of increased assistance after the war.

Turning to the electrical side of the Committee's activities, it is interesting to note the large amount of preparatory work of importance which has been successfully carried through during the past two years. The most important electrical work completed is that of the Standardisation Rules for Electrical Machinery, in the preparation of which the Committee has received the cordial co-operation of the British manufacturers through their official organisation.

The conditions of the electrical industry in this country are very different from those existing either in Germany or America. In the United States two large corporations deal with practically the whole of the business, whereas here there are some 40 or 50 firms more or less in competition with one another. However, conferences held both in London and in New York with the Standards Committee of the American Institute of Electrical Engineers, have resulted in the establishment of a thoroughly practical basis for the comparison of tenders for electrical machinery made in the United States of America or Great Britain, the rules of both countries being now in agreement on all essentials.

It is a pleasure to be able to place on record the Committee's appreciation of the courteous manner in which our American cousins have co-operated with their British confrères in this important matter, and the generous way in which they have dealt with the British criticisms of their original proposals. The result of such work cannot fail to exercise a most beneficial effect in doing away with misunderstandings, and so promoting fair dealing in international contracts.

Much also has been accomplished in one of the most difficult of tasks, the standardisation of small electric fittings with due regard to liberty in design. This work, in which again the makers' association has been most helpful, has occupied a great deal of time, and the difficulties and prejudices to be overcome have been great. Ordinary household wall plugs and sockets have at last been standardised as regards interchangeability. A specification to secure interchangeability between any charging plug and any socket of the type recommended by the Electrical Vehicle Committee of the Incorporated Municipal Electrical Association should be of material assistance in promoting the use of electric wagons and runabouts. A specification for electric supply meters has recently been evolved after much labour, and although some modifications may still be required, it is hoped that it may eventually prove satisfactory to both producer and purchaser alike.

A system of British standard graphical symbols for use in electrical engineering plans is being drawn up, and in this work the Committee has the co-operation of the American and Canadian Electrotechnical Committees.

The ramifications of the Committee are extremely widespread, and the commerce of the world, due to the increasing ease of communication, being largely international, one might almost say in spite of the artificial barriers set up by different nations, it is natural that the Committee should be forced to envisage co-operating internationally. The Sectional Electrical Committee, with a different chairman, is, *ipso facto*, the British Committee of the International Electrotechnical Commission, which has branch committees in 15 to 20 different countries.

The complex nature of electrical machinery calls for different treatment, from the point of view of standardisation, than in the case of other engineering materials. Indeed, the problem of the rating of electrical machinery is, possibly, more intricate than is the standardisation of any simple pieces of mechanism, electrical or otherwise. The conductivity of the copper, the permeability of the iron, the mechanical strength of the materials, can be estimated with sufficient accuracy from the results of definite and easily-carried-out tests on samples. When the question of the insulating materials, however, is considered, the problem is, of course, very different, and one can but acknowledge that, owing to their inherent properties, the insulating materials employed at present come into an entirely different category. They are governed by no well-defined laws, as in the case of the copper and iron, their properties are variable and alter largely for very small changes in the conditions of manufacture as well as those under which they are employed in the completed machine. One of the important problems, therefore, is the settling of the limits which it is considered necessary to impose in order to ensure that the principal causes of destruction of the insulating materials, the heating combined with the time element, shall be well kept within safe limits.

A clear distinction exists also between an "international standard of quality" and an "international rating." The international acceptance of the former has already been brought about by the adoption, by the I.E.C. at its Berlin meeting in September, 1913, of certain limits of observable temperature applying to the materials in general use to-day. But these limits do not offer a means of comparing directly machines from various sources, since they would not necessarily have the same temperature rise. The fact, however, that American and British electrical engineers are at one on this point of immense commercial importance will doubtless have a great influence on the electrical industry of the world.

On all sides there are signs of strenuous preparations for meeting conditions after the war; science and industry are coming closer together, the commercial and technical sides inseparably linked together are being more efficiently organised, research work to assist manufacturers is being co-ordinated, finance is organising, combinations of commercial organisations are in the air; in fact, everything is being done with a view to strengthen British industry.

The German League of Economic Associations recently formed out of the six great associations of German engineers, architects, furnacemen, chemists, electricians, and marine engineers, numbering, so it is said, some 60,000 members, is an indication of what may be expected. Every effort must, therefore, be made to ensure that the British Standard Specifications are readily available to foreign purchasers as well as to those in the British Empire. A few of the specifications have already been translated into French, and it is hoped that satisfactory arrangements may be made to translate them all both into French as well as Spanish. In regard to Russian, the question is somewhat complicated, but in this case also the matter is being given the most careful consideration.

In conclusion, I cannot do better than refer to the views

expressed by Sir John Wolfe Barry at Glasgow, in 1908, for they are true to-day. In many markets, formerly exclusively British, he said, we no longer hold supremacy, because, by quickness of dispatch rather than through superiority of material or workmanship, our rivals have been able to beat us; but the work which has been effected by the Committee should very materially assist in keeping the trade of our great Colonial Empire in the hands of British manufacturers.

Sufficient evidence, you will agree, has been brought forward to show the great utility of the Committee's work to the engineering industry of the Empire. As regards the immediate future, so pregnant with vital issues to our trade, both home and export, the influential position of the Engineering Standards Committee as the central body, with its unique expert knowledge of standardisation, surely holds vast potentialities for good to the industry. The question of standardisation is, indeed, a national one and should be regarded in the broadest way possible. Undoubtedly it is exercising a profound effect on the industry generally and, if supported at home and abroad not only by the British Government but by all concerned, as it richly deserves to be, will, in the future, prove of incalculable value in furthering the legitimate aims of our British manufacturers, the products of whose workshops, for solidity, for efficiency, and continuity of service, are second to none.

UTILISATION OF BLASTFURNACE SLAGS.*

BY E. C. BROWN.

THE hot slag ladle is used at many furnace plants, especially the larger ones, and is essentially a big cast-iron pot, at first carried by a yoke supported on railroad car trucks, but now a more stable cast-iron or steel skeleton car body is employed to support the ladle and its accessories. The transportable pot or ladle thus formed has the necessary tilting mechanism, operated by hand, steam, or compressed air, and the modern ladles have a capacity of about 200 cub. ft. to 260 cub. ft.

The cost of this type of equipment is heavy, both in original outlay and maintenance. The molten slag is run directly from the furnace by the cinder trough into these ladles, and hauled to a convenient dump, sometimes as far as eight or ten miles. The ladles are placed on a track on the edge of the dump and unloaded by tilting. With the modern air-dumped ladle this operation is quite expeditious. It requires only about two minutes per ladle, or from 15 to 20 minutes to discharge the contents of a train of seven or eight cars. Usually the skull or hardened shell of slag slips from the ladle with, or immediately following, the liquid slag. Occasionally the skull tends to adhere to the iron pot, particularly if the latter has been cracked or is otherwise defective. It is usually easily forced out, however, by a few dashes of water thrown from a bucket and aimed at the point of contact between skull and pot. Manifestly, the higher the dump the more economical is this manner of disposition.

From slags thus or similarly deposited, the greater amount, perhaps, of the principal commercial slags are produced. It generally is left to cool and weather for several months, and is then excavated by steam shovel and crushed and screened to various sizes for use as ballast, concrete aggregate, road metal, roofing slag, filter material, &c.

The granulation of slag destroys its dense condition and produces a light and more or less fine granular substance, resembling in appearance coarse sand. In this form the slag will weigh, perhaps, from one-fifth to one-third only as much, volume for volume, as when it is cooled naturally in mass. There are two methods, essentially alike, by which this granulation is accomplished, the second method being rather an improvement of the first, or simpler one. This simpler method is that used at many blastfurnaces, where the molten slag is run directly into a tank, or brick or concrete pit, partly filled with water, in which the disintegration of the slag is accomplished by simple contact with water. This product contains many light, fluffy particles in addition to those of finer and denser character, and much of it is as coarse as popped corn, which, when the colour is light enough, it rather resembles. Owing to its great porosity, much of it floats until it becomes cold and saturated with water and only the denser particles settle at once to the bottom of the tank.

The second method, sometimes called "gun granulation," may be briefly described as follows: The molten slag is delivered from the furnace, through the ordinary trough or runner, to a concrete pit, at the edge of which the trough takes the form of a large nozzle, fitted with an annular ring, from which issues water in the form of spray delivered through a 4in. pipe under pressure of from 30lbs. to 40lbs. per square inch. This causes disintegration and partial cooling of the slag, which operations are further accomplished by the water which partly fills the pit, and by the force of the impact with which the slag is thus driven against the opposite wall of the pit. This product is considerably more dense and heavy than that of the method described above and has been used to some extent as a substitute for sand in concrete work. A modification of this method is the introduction of a jet of air or steam under high pressure, and the use of little or no water. By further modifying the apparatus a substance, very much like commercial mineral wool, has also been produced experimentally.

Notwithstanding considerable variation in both the chemistry and the physical properties of blastfurnace slag, there is a fair degree of uniformity in this material. The differences which exist are due partly to the variation in chemical composition, but probably equally to physical causes or methods of operation and treatment. Generally speaking, calcium and magnesia together form approximately 50 per cent., while silica and alumina make up most of the remainder of the slag. Typical analyses of blastfurnace slags from lake ores under hot-blast practice, are as follows:—

	By Campbell. Per cent.	By Carnegie Steel Company. Per cent.	Per cent.
Silica	35·55	35·00	35·22
Alumina	12·05	15·00	13·68
Calcium	40·52	44·60	43·00
Magnesia	8·86	2·60	5·74
Iron oxide	0·68	0·50	0·49
Sulphur	1·66	1·60	1·61

There are, of course, due to variations in the fluxes and ores, rather extreme variations in analysis, but generally we are not interested in them in considering the slag problem from a utilisation point of view.

In this connection it may be wise to refer to the question which has been raised by some engineers and others, as to the effect of sulphur or other elements, such as magnesia, in slag, which might prove injurious to reinforcing metals placed in slag concrete or which would produce injury through chemical action as by expansion. We may say that practically all blastfurnace slags are decidedly basic in character, there being almost always present some excess of free lime, and the small amounts of sulphur which occur, the chemists say, are present as sulphides only, and are, therefore, harmless to metal. As a practical matter, there are numerous instances on record where anchor bolts and other forms of iron or steel, embedded for reinforcing or other purposes in slag concrete, have been removed after several years and found to be in perfect condition, no corroding or other injurious influence having affected them.

Perhaps the most extensive use of commercial hard slag to-day is in road improvement work in which it has given most satisfactory results. This is so whether in plain water bound macadam or in combination with tars, asphaltes, or other special binders. As an aggregate in concrete for all general purposes, slag has been most thoroughly tested and is far beyond the experimental stages. It has gone into all kinds of buildings, walls, bridge work, light reinforced structures, as fence posts and telegraph poles, floors, roof slabs, and in fact into practically everything for which concrete of any kind is suitable. In not a few classes of construction it is especially well adapted because of its relative lightness, good bonding qualities, and perfect fire-resisting nature.

An average commercial blastfurnace slag has a specific gravity of about 2·62; limestone averages 2·60; granite, 2·68; and trap rock, 2·96. Slag is of a greyish colour, breaks with decided angularity, is somewhat porous, and weighs commercially approximately 2,000lbs. per cubic yard. Of these qualities, perhaps the most important, or at least the most conspicuous, is its porosity, which may be more properly characterised as a cellular construction. This accounts for its relative light weight, both in the natural fragment and in

* Abstract of paper read before the Engineers' Society of Western Pennsylvania.

combination, as, for instance, in concrete. The weight of some of the forms of blastfurnace slag is as follows: Crushed and sized bank slag, as ordinarily produced and shipped, weighs 1,900lbs. to 2,100lbs. per cubic yard, probably 2,000lbs. is very near the average. Granulated slag varies greatly, probably from as low as 800lbs. to 900lbs. to as high as 1,500lbs. to 1,600lbs. with an average of 1,300lbs., both fineness and moisture greatly affecting the weight.

HEAT-TREATED STEEL.

BY LAWFORD H. FRY.

HEAT treatment is much like strong medicine. Applied by a skilled doctor under proper conditions it gives excellent results, but in unskilled hands the consequences are disastrous. In fact, after reviewing some of the early unhappy examples of heat treatment one might well borrow Madame Roland's phrase regarding liberty, and exclaim, "How many crimes have been committed in thy name!" Though mistakes have been made in the past it is undoubtedly true that the net balance is on the credit side, and that the field for the use of properly treated material is bound to extend.

Our aim here is to discuss the proper production and the proper use of heat-treated material for railway service. The most important phases of the subject are brought out in the following four questions and answers, and the facts on which the answers are based are examined later in detail.

Q. 1.—What advantages has heat-treated material over untreated material, and when should treated material be chosen?

A.—Heat treatment gives to steel a high elastic limit and high tensile strength combined with good ductility. As a consequence greater strength with the same weight and dimensions, or less weight with the same strength, can be obtained. The treated material should be chosen when these advantages outweigh the higher cost.

Q. 2.—How are the above qualities obtained?

A.—By heating the material to the proper temperature, quenching it in oil or water to confer great strength and hardness, and reheating to a lower temperature to remove some of the hardness and restore ductility.

Q. 3.—What is necessary for the production of satisfactory heat-treated material?

A.—Sound and carefully selected steel, knowledge of the proper temperatures to use, furnaces and apparatus for accurately obtaining and measuring these temperatures, and a proper installation for quenching.

Q. 4.—What precautions are necessary in repair work on heat-treated material?

A.—Any bending or straightening must not be done cold, but at a temperature of between 900° and 1,000° Fah. No higher temperature must be used, or the special properties given by the treatment will disappear. Retreatment should never be attempted except where heat treatment is usually done and where apparatus and experience are available.

So far we have spoken of heat-treated steel without specifying forged or cast steel. While some heat-treated castings are used, heat-treated forgings are more important in railway work, and in what follows attention will be directed to them; the greater part of what is said about heat treatment, however, will apply to castings as well as to forgings.

The quality of any forging and its suitability for service depend on two things—first, on the chemical composition of the steel, and second, on the physical structure of the steel as determined by the working and heating it has undergone. The chemical composition is fixed at the time the ingot is poured, but the physical structure as disclosed by the microscope is varied by every operation of heating or working. In the ingot the structure is large grained and open, corresponding to a moderate hardness and low ductility. As the ingot is reduced to a billet by rolling, the grain becomes finer and the structure more compact, the exact condition depending on the amount of work done on the steel and the temperature at which it is done. The same process of improvement by refining the grain also takes place when the billet is made into a forging. Both the strength and the ductility of the metal are increased, and it is in much better condition to resist stresses and shocks. It is difficult, however, to control the temperature at which the forgings are finished, and impossible to have the temperature at which they leave the hammer uniform throughout. As a consequence the structure of the steel will not be uniform, and the unequal cooling may set up severe shrinkage strains. To eliminate these strains and to secure a uniformly satisfactory structure it is desirable, in the case of forgings for railway service which are not to be heat treated, to heat them to a temperature which will refine the grain and then allow them to cool uniformly—in other words, to anneal them. The consequences of the annealing are a slight loss in tensile strength and a considerable gain in ductility.

In the heat-treated forging a further step is taken. The quenching refines the grain still further and establishes a new condition in the structure, conferring on the steel superior qualities which cannot be secured otherwise. Observed from the outside the steel is seen to be heated to a certain temperature and then quenched in oil or water. This makes it hard and brittle; too hard to machine and too brittle to stand shocks. It is therefore tempered by being reheated to a lower temperature and allowed to cool slowly. This reheating removes some of the hardness and gives ductility. The extent to which the drawing of the temper is carried will depend on the service for which the forging is intended and the qualities desired. Viewed internally, by means of the microscope, it will be seen that the quench greatly refines the structure and introduces another modification which tends to disappear on the draw. The exact reasons for these changes may be left to the metallurgists. The facts of practical importance are that as steel is heated it passes through a certain critical range of temperature in which its structure changes to a form which, if preserved when cold, will produce a very hard material. Slow cooling allows this structure to disappear, but by rapid cooling, such as quenching, some of this hardening structure can be retained. The more rapid the quenching, the more nearly is the hardening structure retained and the harder will be the steel. As the steel is reheated after quenching the hardening structure gradually disappears, and by stopping the reheating at the proper point any desired degree of hardness below that given by the quench can be obtained. If the reheating is carried to the critical temperature all of the hardening structure will have disappeared, to reappear after the critical temperature has been passed. The steel will now be in the same condition as before quenching, and will be soft if cooled slowly (annealed) or hard if again quenched.

One of the problems of heat treatment is to determine the location of this critical temperature, and to decide on the margin above it to which the steel should be heated before quenching. A certain margin is necessary to secure satisfactory results in practice, but if this margin is exceeded the grain will be coarsened. It is impossible to give general rules for quenching temperatures, because so much depends on the composition of the steel, the design and dimensions of the forging, and on the conditions of the quenching. Under the conditions described below, a temperature of 1,475° Fah. in the furnace before quenching will give satisfactory results with a locomotive driving axle of steel containing 0·40 per cent. carbon, but a different temperature would be required if the carbon content be changed or if alloy instead of carbon steel be used.

The standard forging specifications of the American Society for Testing Materials will serve to compare the properties of heat-treated with those of annealed forgings. Taking, for example, a locomotive driving axle about 11in. diam., the minimum tensile properties required for carbon and alloy steel are as follows:—

Material.	Elastic Limit. Lbs. per square inch.	Tensile Strength. Lbs. per square inch.	Elongation in 2in., per cent.	Reduction of Area, per cent.
Carbon—annealed	40,000	80,000	21·6	33·0
Carbon—quenched and tempered	50,000	85,000	22·3	42·3
Alloy—quenched and tempered	65,000	90,000	20·0	50·0

Generally speaking, the allowable working fibre stress is determined by the elastic limit, so that in the carbon steel the quenched and tempered material is 25 per cent. stronger than the annealed material.* By substituting heat-treated

* This is a conservative statement, as the figures given for the annealed forgings are for yield point, and not for elastic limit; while for the treated material the elastic limit is given.

alloy steel for the annealed carbon steel the strength can be increased over 50 per cent.

As has been pointed out, under conditions in which this increase in strength is worth the increased cost, the treated material is desirable. As an instance of this kind, consider the valve motion and reciprocating parts of a locomotive. Weight here is a great disadvantage, and at the same time the use of high grade material will not very greatly affect the total cost of the locomotive.

In producing heat-treated forgings, the first problem to be encountered is the selection of sound steel. This is a difficult subject, for while it is well recognised that the steel must be of good quality it is not easy to lay down hard-and-fast rules for its selection. One large consumer specifies that the carbon segregation between centre and outside shall not exceed 12 per cent., but this requirement has not yet stood the test of time. For our purpose it will therefore be assumed that the manufacturer, by the best use of his judgment and his conscience, will choose good steel and forge it by proper methods.

In the process of quenching and tempering two points require consideration: the heating and the quenching. It is essential that the heating be done uniformly and accurately. The furnace should be so designed that at no point will the temperature vary more than 10° Fah. to 15° Fah. from that desired, and should be equipped with sufficient pyrometers to enable the operator to be certain that this degree of accuracy is being obtained. The quenching system must be placed so that the heated material can be transferred to it from the furnace without loss of time or temperature. It must also be arranged so as to extract from the material the required amount of heat at the desired rate. Here, in the quenching system, the success or failure of the treatment will be determined, and it is here that experience is necessary.

In quenching, the balance must be held between two conflicting requirements. Rapidity of cooling is desirable to retain the hardening structure, but brings with it severe shrinkage strains, which, if not controlled, may destroy the material. To illustrate the character of the shrinkage strains and the damage they may cause, a locomotive-driving axle will be considered. On entering the quenching medium the outer surface is chilled by contact with the fluid and therefore tends to contract, while the inner part of the axle, not having the same opportunity for cooling, does not shrink in the same proportion. As the outer surface shrinks it has to adapt itself to the enlarged central core, and in so doing must be stretched. If the cooling of the surface is too rapid, or if there is any considerable seam or flaw, the stretching necessary for adjustment may be beyond the capacity of the steel, and a longitudinal crack may start in the outside surface. If the cooling is somewhat less rapid the outer shell will adapt itself to the hot core; then, as the cooling effect penetrates, a shell next to the surface shell cools and stretches, and this action is continued. It will be seen that as the end of the cooling approaches the axle consists of an outer cylinder stretched, but rigid, enclosing a central core which, in order to complete its cooling, has to undergo a shrinkage tending to make it occupy less space than that held for it by the cooled cylinder. This sets up a very considerable stress at the centre of the axle, and if the cooling is allowed to complete itself too rapidly a radial fracture will be set up starting from the centre of the axle.

For convenience an axle has been considered, but a similar condition will be found in any forging having any considerable thickness. In a bored axle the shrinkage strains are much less than in a solid axle, for two reasons: First, the quenching fluid acts both inside and outside, producing more uniform cooling; second, the hollow cylinder is a less rigid form and avoids the difficulty of the final cooling of the central core.

So far we have considered only the shrinkage in directions perpendicular to the axis of the axle, but a very similar action takes place in a direction parallel to the axis. A chilled, rigid cylinder is formed enclosing a hotter cylinder which has still to complete its shrinkage. In the final shrinkage if too rapidly completed, the middle part of the core may pull away from the ends, a transverse fissure starting in the interior of the axle and not emerging through the outer shell until some shock is received after the treatment is completed.

To avoid internal fissures it is desirable not to let the forging cool all the way down to the temperature of the quenching medium, but to remove it from the tank and send it back to the furnace for drawing the temper while the temperature of the interior is still 400° Fah. or 500° Fah. During the reheating and subsequent cooling the shrinkage strains have time and opportunity to equalise.

The external cracking first mentioned is less likely to occur than the internal cracking, and will only take place if the material is defective or if the quenching medium gives too severe a shock when the forging is first dipped.

Water, heavy oil, a mixture of oil and water, and many special brands of quenching oils are advocated and used as quenching mediums. Water has the advantage of conferring excellent physical properties by reason of the rapid cooling, but for the same reason will produce dangerous shrinkage strains unless the cooling is very carefully timed. Heavy oil, such as cylinder oil, greatly reduces the danger from cracking, but quenches more slowly, and therefore does not produce such good physical properties in the steel. With a view to reducing the danger of damage by water, and at the same time securing better results than can be obtained with heavy oil, various other quenching fluids are used. Some manufacturers use a mixture of oil and water similar to a drilling compound, while others use light oils of different grades. The light oils introduce a fire risk, but this need not be serious if sufficient volume of oil is provided and steps taken to prevent its temperature from being unduly raised.

The writer advocates the use of an inexpensive light mineral oil with a fire point of about 390° Fah., a flash point of about 350° Fah., and gravity about 29° Baumé. There should be separate quenching and storage tanks, the latter to have ample capacity and to be provided with cooling coils. The oil should be pumped from the storage into the quenching tank, and delivered into the latter in such a way as to produce a vigorous and positive circulation about the object to be quenched. A system of this kind has many advantages, one of the most important being that since the circulation of the oil is controlled by the pump, the rate of circulation can be varied, and the rate of cooling thus adapted to suit the needs of almost any case. Experience will show the rate of cooling desirable for each class of forging, and good results can be obtained with small risk of cracking. To be on the safe side and to avoid any possible trouble with internal cracks it is considered good practice to apply a proof test to every heat-treated forging. This usually takes the form of a drop test sufficient to eliminate any defective, but not sufficient to injure any sound forging.

With a quenching system as described, with care in its use and in the selection of the steel, and with a proof test on each forging after treatment, manufacturer and consumer can rely on the product being uniform and satisfactory.

It is undesirable to attempt to bend or to straighten heat-treated material cold, as this will set up cold-work strains. At the same time it is obvious that if the temperature be carried above that at which the material was drawn, the strength conferred by the treatment will be lost. It must always be remembered that heat-treated material possesses its good qualities because it has been heated to certain temperatures in a certain way, and that if heated again to these temperatures the quality will be affected. It should be obvious from what has been said that material cannot be retreated at a repair point unless full equipment and experience are available.—"Railway Mechanical Engineer."

Mansion House Engineering Meeting.—In view of the national prominence of the engineering industry, the Lord Mayor of London is convening a public meeting at the Mansion House, at 3 p.m. on Wednesday, September 20th, to discuss future trade policy with special reference to the economic utilisation of the engineering works of the nation which have been so largely expanded in capacity and equipment during the past two years. The organisation of the meeting is being undertaken by the British Electrical and Allied Manufacturers' Association, with the support of the British Engineers' Association, the British Empire Producers' Organisation, and the Engineering and Electrical Sections of the London Chamber of Commerce. Applications for tickets of admission should be sent to Mr. T. C. Elder, organising secretary for the meeting, B.E.A.M.A. Offices, 36, Kingsway, London, W.C., or to the secretaries of any of the above organisations.

LAPS AND LAPPING.

In a paper on the above subject presented before the American Society of Mechanical Engineers by W. A. Knight and A. A. Case, the following conclusions were arrived at:—

(1) The initial rate of cutting is not greatly different for the different abrasives.

(2) Carborundum maintains its rate better than either of the others, alundum next, and emery the least.

(3) Carborundum wears the lap about twice as fast, and alundum $1\frac{1}{4}$ times as fast as emery.

(4) There is no advantage in using an abrasive coarser than No. 150.

(5) The rate of cutting is practically proportional to the pressure.

(6) The wear of the laps is in the following proportions: Cast iron, 1·00; steel, 1·27; copper, 2·62.

(7) In general, copper and steel cut faster than cast iron, but where permanence of form is a consideration, cast iron is the superior metal.

(8) Gasoline and kerosene are the best lubricants to use with cast-iron lap; kerosene, on account of its non-evaporative qualities, being first choice.

(9) Machine and lard oil are the best lubricants to use with a copper or steel lap. They are least effective on the cast lap.

(10) For all laps and all abrasives (of those tested) the cutting is faster with lard oil than with machine oil.

(11) Alcohol shows no particular merit as a lapping lubricant.

(12) Turpentine does fairly good work with carborundum, but in general is not as good as kerosene or gasoline.

(13) Soda water compares favourably with other lubricants. Taken as a whole, it is slightly better than alcohol and turpentine.

(14) Wet lapping is from 1·2 to 6 times as fast as dry lapping, depending on material of the lap and the manner of charging.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Friction clutches. Walker, and Smith & Coventry, Ltd. 11409.
Centrifugal fans and pumps. Davidson. 11995.
Valves. Morris. 12056.
Wrenches. Haas. 12135.
Automatic traps for draining oil separators, condensers, &c. Baker, and Bakers (Leeds), Ltd. 12349.
Method of operation for internal combustion engines. Dumanois. 12821.
Devices for controlling the furnaces of low-pressure steam boilers. Mellersh Jackson. 13248.
Rotary piston internal-combustion engine. Wheatley. 13677.
Internal combustion engines. Samain. 17724.
Wrench. Holmes. 17821.

1916.

Air compressors. Reavell, W., and Jones, E. W. 345.
Means for supplying air to furnaces. Brown, W. H. 2529.
Pistons. Chedru, G. E. 3045.
Measuring indicators or gauges. Hart, A., and Almfelt, K. J. 4012.
Water tube boilers. Noble, E. E. 4605.
Spanners. Allen & Hanburys, Ltd., and King, P.S. 5954.
Pipe wrenches. King, H. 6477.
Automatic clutch releases. Brettell, F. G. 10744.

ELECTRICAL, 1914.

Regulating means for electrical installations. Soc. Anon. des Etablissements L. Bleriot. 23075.

1915.

Electric supply systems for use with internal combustion motors. Marks. 12000.
Electric distribution systems. Frampton, and Callender's Cable and Construction Company. 12103.
Controllers for electrically-driven vehicles. Turner. 15304.
Wireless telegraphy. Marconi's Wireless Telegraph Company, and Bangay. 16151.
Electric starters for internal combustion engines. Brooks & Holt. 17008.

1916.

Secondary or storage batteries. Wade, H. 2085.
Means for regulating the voltage of a direct-current dynamo. Schneider, E. 3114.
Sparking plugs. Guinness, K. E. L. 6603.
Electric furnaces of the electrode type. Kitchen, H. J., and Balmforth & Co., T. 8533.

METAL QUOTATIONS.

TUESDAY, SEPTEMBER 12TH.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled	1/3⅜ per lb.
,, tubes (brazed)	1/5¼ ,,
,, ,, (solid drawn)	1/3¼ ,,
,, ,, wire	1/2⅞ ,,
Copper, Standard	£111/10/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£31/15/– ,,
,, Foreign (soft)	£29/15/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	32$\frac{5}{16}$d. per oz.
Spelter (American)	£45/–/– per ton.
Tin, block	£169/10/– per ton.
Tin plates, I.C.	32/– per box.
Zinc sheets	£72 per ton.

Acoustic Properties of Buildings.—When the large auditorium at the University of Illinois was built in 1908 it proved to be unsatisfactory in its acoustical properties. Audiences found it difficult to hear speakers owing to marked reverberation and echoes. Dr. F. R. Watson, of the Physics Department, and James M. White, Supervising Architect, undertook to correct this fault by conducting a systematic investigation involving a long series of experiments. "Bundles" of sound were projected in different directions and the paths of these were carefully traced. Various instruments, such as a ticking watch, a hissing arch lamp, and megaphones, were employed and curtains and draperies were hung at critical points suggested by the diagnosis. Certain of the walls were then covered with hairfelt mounted on thin furring strips, with the result that at present a speaker with a moderate voice may be heard distinctly by auditors in the most distant seats of the large building. The investigations are described in detail in an illustrated booklet issued by the Engineering Experiment Station as Bulletin No. 87. Copies may be had by addressing W. F. M. Goss, Director, Urbana, Illinois.

Electricity Supply.—A conference has taken place between the Electricity Supply Committee of the Institution of Electrical Engineers, the Joint Committee of the Incorporated Municipal Engineers' Association, and the Incorporated Association of Electric Power Companies regarding co-operation between the committees. These committees are constituted as follows: The I.E.E. Committee: Messrs. R. A. Chattock (chairman), C. P. Sparks (president, I.E.E.), C. H. Merz, S. L. Pearce, G. W. Partridge, T. Roles, W. B. Woodhouse. Joint Committee of the I.M.E.A. and I.A.E.P.C.: As representing the Incorporated Municipal Engineers' Association: Messrs. J. H. Bowden, R. A. Chattock, W. W. Lackie, S. L. Pearce, H. Faraday Proctor (ex-officio), T. Roles; as representing the Incorporated Association of Electric Power Companies: Messrs. W. A. Chamen (chairman), J. S. Highfield, C. H. Merz, D. A. Starr, A de Turckheim (ex-officio), W. B. Woodhouse. In order to avoid overlapping and to ensure co-operation and co-ordination, two members common to both committees have been delegated as intermediaries, so that the two committees will be in continuous touch with each other's work. It has been agreed that the I.E.E. Committee shall devote its attention to the question of electricity supply from the point of view of the requirements of the country as a whole, and shall deal with the engineering aspect of the matter, while the Joint Committee will go into more immediate questions of organisation and linking up of existing undertakings, &c.

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The man stood on the boiler top, whence all but he had flown,
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The Practical Metallography of Iron and Steel.

By JOHN S. G. PRIMROSE, A.R.T.C., A.I.M.M., M.I.M.
Lecturer on Metallurgy, and demonstrator on Metallography at the Royal Technical College, Glasgow.

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Every Iron and Steel Works should be provided with a metallographic laboratory with a suitable equipment in which, by Scientific methods, the daily working may be controlled and improved, and that this may be efficient, every worker should be familiar with the principles on which the researches are based. This book has been prepared for the use of those who are commencing the study of metallography. The work is a thoroughly practical one, theoretical considerations being made as brief as possible. The contents comprise exhaustive chapters on Microstructure of Iron and Steel; Constitution of Iron and Steel; Heat Treatment of Iron and Steel; Micrographic Examination of Failures; Metallographic Apparatus and its Manipulation.

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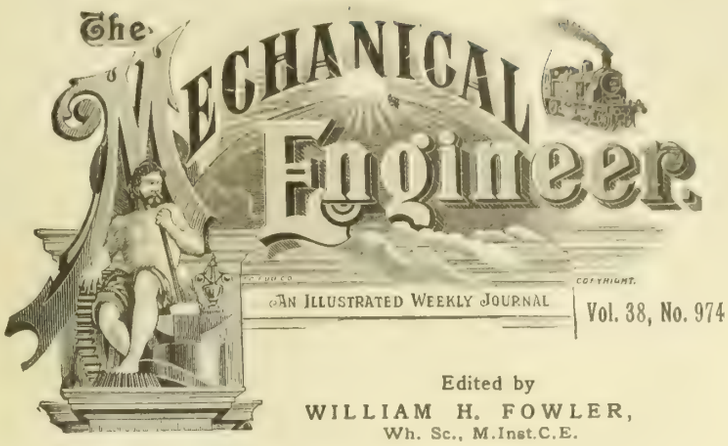

Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

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The Rise and Decline of the Bessemer Process.

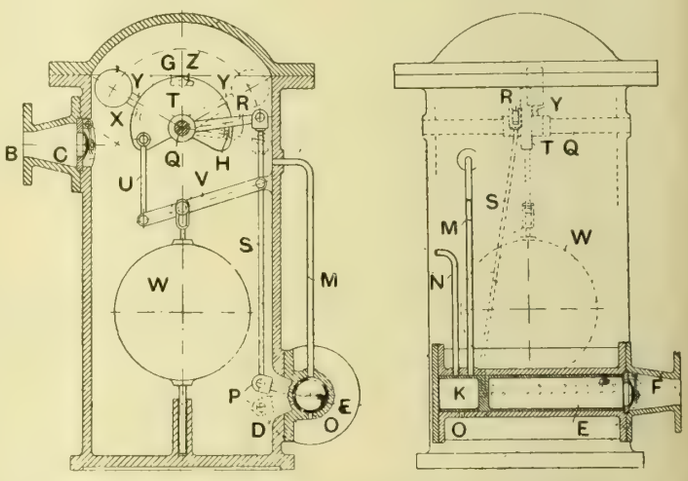
A RECENT issue of "The Iron Age" gives an interesting review of the phases which have marked the career of the Bessemer process of steel manufacture in Great Britain and the United States, its phenomenal growth at the commencement, and the steady decline that has marked the output in comparison with other processes during recent years. Invented in 1856, it was not till some years afterwards that its merits were realised, and it was but natural that Great Britain as the home of the invention, and the possessor of large deposits of pure ore suitable for the acid process, should first show its revolutionary effects on steel output. Between 1860 and 1870 rapid progress was made both here and abroad, but at the latter date this country stood easily first in the list of steel producers, and its decline from this position was largely owing to the exhaustion of the hematite mines of Cumberland and Lancashire which produced a pig iron containing only about 0·04 per cent. of phosphorus. Half-a-century ago there was no special demand for pure ore, and the output of the district was limited. With the advent of Bessemer steel, however, these deposits became very important, and it was shipped extensively not only to the continent, but also to the United States. In 1860, the output was rather less than one million tons. By 1870 it had grown to over two millions, and in the next decade to over three millions, the maximum being reached in 1882 with 3,136,000 tons. After this the output steadily decreased owing to the exhaustion of the mines, and to-day is only about half what it was 35 years ago. The loss of this natural advantage was to some extent compensated by the importation of the deposits of pure Spanish ore from the neighbourhood of Bilbao. Prior to 1860 no foreign ore was imported, and in 1870 the amount was only 400,000 tons, which accounted for less than 4 per cent. of the total amount of pig iron produced at that time. Since then, however, these

imports have steadily increased. In 1913 they amounted to close on 7½ million tons, and accounted for no less than 38 per cent. of all the pig iron produced. Thus, while in 1870 imported ores only accounted for 15 per cent. of the Bessemer pig iron produced in Great Britain the proportion in 1882 had grown to 50 per cent., and in 1913 had reached to as much as 76 per cent. Though Bessemer steel-making in the United States made some progress in the early years of its development it was not till the eighties that the latter country displayed its latent possibilities, and by its improved transport facilities on the Lakes enabled the Pennsylvania Steel Works to tap the vast iron deposits of Michigan. Since then the American steel output has marched with giant strides which do not yet show signs of diminishing, and some idea of which may be gathered from the fact that in 1913 the output of Lake Superior ores was no less than 50 million tons, an amount which would make more pig iron than all the ores mined in Great Britain, Germany, France, Austria, and Belgium put together. Side by side, however, with this enormous expansion in total output of ore in the States is the fact that the proportion of acid Bessemer steel has of late years been showing a steady decline in favour of other processes, notably the basic open-hearth. In Great Britain the maximum was reached in 1890. The decline since then has been continuous, and in the last few years has been especially notable. On the other hand, the proportion of Bessemer steel increased up to 1896, since when there has been a tendency more and more pronounced for the open-hearth to push the converter more and more into the background, and from a consideration of the figures there can be little doubt that Bessemer steel, as compared with open-hearth for constructional purposes, has lost its supremacy. Taking two five-year periods, 1903-7 and 1909-13, and leaving out 1908 and 1914 as abnormal, it appears that while the total steel output of the United States during these two intervals has increased 43 per cent., the production of Bessemer has on the other hand decreased 9 per cent. A glance at a table of the percentage production of Bessemer for each year since 1901 shows the decline to have been continuous since 1901. In that year it constituted 65 per cent. of the total, and without a break this proportion has dropped till in 1914 it was as low as 26 per cent. While it cannot be said that the death-knell of Bessemer steel has been sounded, it is a clear indication of its lesser relative importance. There must always remain fields of usefulness in which the acid converter, given suitable ores, will, owing to commercial considerations, possess a superiority. From a decline in relative importance to extinction is a big step. Thirty years ago it was the firm belief of many that the old crucible process would be displaced by the open-hearth furnace, but its relative decline as regards output has been quite consistent with the actual output. It is the same with wrought iron. The proportion as a percentage gets less and less, but there still remain certain fields in which its special properties command recognition and from which steel cannot displace it.

AUTOMATIC TRAP FOR DRAINING OIL SEPARATORS AND CONDENSERS.

THE accompanying illustrations show a design of automatic trap or discharger for draining oil separators, condensers, turbine casings, exhaust pipes, or other receptacles which are continuously under vacuum or alternately under vacuum and pressure, the invention of Messrs. Bakers (Leeds), Ltd., Union Works, Hunslet, Leeds.

The casing of the apparatus has at its upper end the liquid inlet B, fitted with a non-return valve C, and at its lower end the discharge outlet D, in connection with which is fitted a discharge valve E and a non-return valve F. The valve E comprises a hollow cylindrical sleeve, provided with a series of perforations and is located in a cylindrical casing having a series of ports corresponding to the openings in the sleeve, so that when the valve is in one position the perforations and ports will coincide to allow of the discharge from the trap, whilst in the other position the ports will be closed. The sleeve is also provided at one end with a chamber K having two openings, one of which places the chamber K permanently in communication with the trap through the pipe M, whilst the other, when the valve is closed and the apparatus is receiving the drainings, places the chamber K in communication with a pipe N, which leads to the apparatus being drained, so that during the normal working of the apparatus the interior of the trap and the interior of the apparatus being drained are in communication and thus in equilibrium. In the chamber K there is also formed an aperture O, which is designed to co-operate with a corresponding perforation in the wall of the chamber, the arrangement being such that when the pipes M, N are in open communication through the chamber K the port O is closed, whilst when the cylindrical valve is rotated to close the pipe N, the port O will be opened to admit air into the trap through the pipe M. The operation of the valve by the float is as follows: Upon a shaft Q is fixed an arm R, the free end of which is connected by a rod S to the valve-operating arm P. Upon the shaft is also fitted a lever T, which is made in the form of a segment of a disc, the lever being connected by a rod U to one end of a lever V, the other end of which is pivoted in the casing, as shown; this lever V has the float W connected to it, the float, having a rod at its lower end, working in a guide, for keeping it steady, and being adapted, as it rises, to move the lever or segment T. Upon one side of this segment are arranged two stops X, G, which co-operate with the arm Y of a weighted tumbler freely mounted upon the shaft Q, and upon the other side of the segment are two stops Z, H, which co-operate with the arm R



AUTOMATIC TRAP FOR DRAINING OIL SEPARATORS AND CONDENSERS.

through the medium of which motion is communicated to the valve E.

The operation of the apparatus is as follows: Assume the parts to be in the position shown, that is to say, in the position wherein the float W is at its lowest point and the discharge valve E closed. In this position of the parts the chamber to be drained and the interior of the trap are in communication through the pipe N, chamber K, and pipe M, so that the liquid is free to enter the trap through the inlet B. As the level of the liquid in the trap rises and lifts the float W, the movement of that float gradually rotates the segment T and raises the tumbler arm Y until the latter is moved slightly beyond a vertical position towards the discharge side of the trap, whereupon the tumbler, owing to its weight, will fall and suddenly move the segment so that the stop Z thereon impinges against the arm R to open the discharge valve E, with the result that the perforations therein are caused to coincide with the ports in the valve casing and that the trap is cut off from communication with the vessel to be drained through the pipe N and opened to the atmosphere through the port O whereby the liquid from the trap can flow out. As the trap gradually empties the weight of the float and the connected parts moves the segment T so that the stop G acts upon the tumbler lever Y to move it in the reverse direction, that is to say, toward the inlet side of the trap, and directly the tumbler lever has passed the vertical position it drops on to the stop X and so moves the segment T to cause the stop H to impinge against the underside of the lever R to lift it and close the valve E, when the parts are again in the normal position for work.

LIMIT GAUGES*

BY DR. R. T. GLAZEBROOK, F.R.S.

(*Concluded from page 203.*)

II. *Screw Gauges.*—The problem of the standardisation of screw limit gauges is a very difficult one; a screw surface is a complex form, and to satisfy oneself that in all its dimensions it lies within certain limits involves much careful work. The question is fully discussed in the E.S.C. Report No. 38, February, 1913, on British Standard Systems for Limit Gauges for Screw Threads, and the following definitions are taken from the report:—

Effective diameter.—The effective diameter of a screw having a single thread is the length of a line drawn through the axis and at right angles to it, measured between the points where the line cuts the slopes of the thread (Fig. 4).

Core diameter.—The core diameter is twice the minimum radius of a screw, measured at right angles to the axis (Fig. 4).

Full diameter.—The full diameter is twice the maximum radius of a screw, measured at right angles to the axis (Fig. 4).

Crest.—The crest is the prominent part of the thread, whether of the male screw or of the female screw (Fig. 5).

Root.—The root is the bottom of the groove of the thread, whether of the male screw or of the female screw (Fig. 5).

Slope of thread.—The slope of thread is the straight part of the thread which connects the crests and roots (Fig. 5).

Angle of thread.—The angle of thread is the angle between the slopes, measured in the axial plane (Fig. 5).

Note.—From Fig. 4 it will be seen that the "core diameter" of the male thread is measured between the roots of the threads; it should be borne in mind, however, that the "core diameter" of the female thread, being approximately the same dimension, is measured between the crests of the thread.

Pitch.—The pitch is the distance in inches measured along a line parallel to the axis of the screw between the point where it cuts any thread of the screw and the point at which it next meets the corresponding part of the same thread (Fig. 5). The reciprocal of the pitch measures the number of turns per inch or millimetre, as the case may be.

In the Whitworth thread standardised by the committee there are seven elements, and error in any one of these may be sufficient to cause a gauge to reject work which ought to pass, or vice versâ. These elements are as defined already: Full (or major) diameter; core (or minor) diameter; effective (or pitch) diameter; pitch; angle; form at crest; form at root. Of these the most important and the most difficult to control are the pitch and the effective diameter. In the Whitworth thread the attempt is made to obtain contact over the whole surface of the screw; while possibly for some purposes this is desirable, it adds greatly to the difficulties of both construction and gauging, and there is much to be said for a system which allows definite clearances at crest and root. Four of the above seven elements—the two first and the two last—then become unimportant, and we are left to concentrate on the effective diameter, the pitch, and the angle of the thread. If the screw bears along its slopes it is doing its work satisfactorily, and in most cases the fact that there is clearance at crest and root is immaterial. Before proceeding further it is important to notice that errors in pitch and effective diameter are closely connected (see Fig. 6).

Suppose the full and dotted outline to represent a ring and a plug screw of similar form, but of slightly different pitch. Let the maximum relative displacement of any two threads engaged be $2a$. Then the extreme threads will be displaced axially by $+a$ and $-a$ respectively. A glance at the diagram shows that in this case the parts will not go together unless the axial displacement is accompanied by a radial displacement which, allowing for the angle of the thread, is about equal to $2a$. This is doubled on the diameter, so that as a rough rule it may be taken that any error in pitch has to be compensated by an error of twice the amount in effective diameter. Thus we can compensate for an error p in pitch on a thread of which t inches are engaged by allowing a reduction of effective diameter of $2\,p\,t$ in the plug, or an increase of the same amount in the ring. Some reductions in the full and core diameters are also required, but in consequence of the curves at crest and root these are small, and need only rarely be taken into consideration. Reducing the effective diameter of a plug, or increasing that of a ring screw, has the effect of reducing the thickness of the corresponding thread at that point; the thread is made thin. Thus, in order to compensate pitch errors, makers have a tendency to make their screws thin; they claim an allowance on effective diameter which makes up for the error tolerated on pitch. The Engineering Standards Committee, in their Report No. 38, stated that they have had two separate matters to decide upon:—

"(1) To lay down tolerances on full, core, and effective diameters to cover the wear of tools and unavoidable imperfection of workmanship, and to prescribe minimum allowances in order that bolts and nuts may be assembled freely.

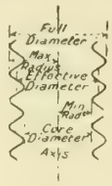


FIG. 4

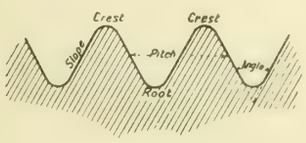


FIG. 5

FIG. 6

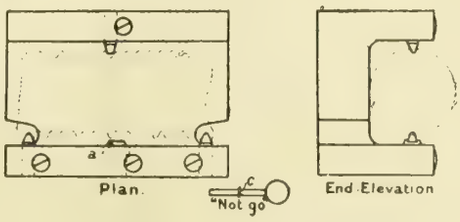


FIG. 7

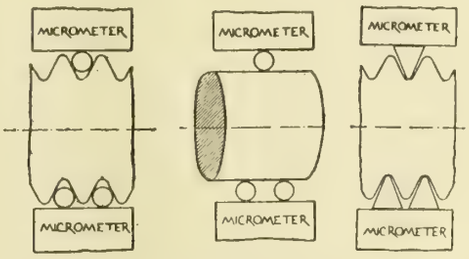


FIG 8

"(2) To decide what errors in pitch could be permitted in ordinary practice, having regard to the allowances, in effective diameter which they entail."

And as a result they recommend a series of tolerances for the two threads considered—British Standard Whitworth, and British Standard Fine—given by the following formulæ taken from Report No. 38 of February, 1913.

B.S.W. Threads.

1 Bolt. Tolerance on full diameter.	2 Bolt. Tolerance on core diameter.	3 Allowance (on the nut).	4 Nut. Tolerance on full and core diameters.
in. $-0{\cdot}0035\sqrt{D}$	in. $-0{\cdot}0045\sqrt{D}$	in. $+0{\cdot}001\sqrt{D}$	in. $+0{\cdot}0035\sqrt{D}$ (above allowance)

B.S.F. Threads.

5 Bolt. Tolerance on full diameter.	6 Bolt. Tolerance on core diameter.	7 Allowance (on the nut).	8 Nut. Tolerance on full and core diameters.
in. $-0{\cdot}0025\sqrt{D}$	in. $-0{\cdot}0035\sqrt{D}$	in. $+0{\cdot}001\sqrt{D}$	in. $+0{\cdot}0025\sqrt{D}$ (above allowance)

D = nominal diameter of thread in inches.
The positive and negative signs refer to the nominal dimensions of the bolt.

* Paper read before Section G of the British Association, at Newcastle, September, 1916.

The report also gives formulæ for the tolerances on pitch, and the allowances on effective diameter required to compensate them, and tables setting out the tolerances on the various elements.

Turning now to the question of providing limit gauges for such threads, we are met with many difficulties. The committee, after a discussion of these, summarised their recommendations thus:—

For Bolts.

1. "Go" and "Not go" gauge of the "Taylor" type for pitch and effective diameter.
2. "Go" and "Not go" double gap gauge for full diameter.
3. "Go" and "Not go" double gap gauge for core diameter.

For Nuts.

1. "Go" standard bolt, correct in all particulars, and made to the minimum diameters allowable.
2. "Not go" single thread gauge for full diameter.
3. "Not go" single thread gauge for effective diameter.
4. "Not go" cylindrical gauge for core diameter.

We shall see shortly what is meant by the "Taylor"* type of gauge. For bolts the three "go" gauges recommended may be, and usually are, replaced by a single "go" ring gauge, a ring screw of correct form and dimensions. Such a gauge is difficult to construct and verify with accuracy;

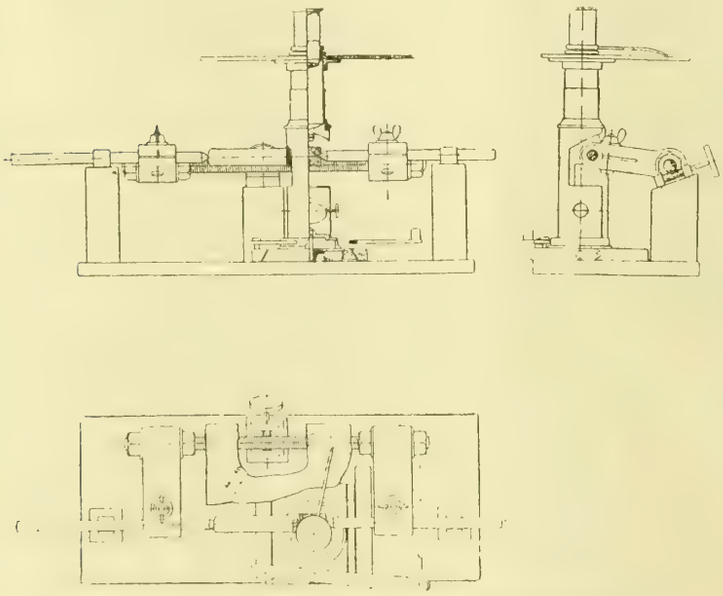


FIG. 9.—MICROSCOPE FOR STUDYING ANGLE AND FORM OF THREAD.

hence Mr. Taylor suggested for pitch and effective diameter a three-point gauge shown in Fig. 7.

The three conical points, accurately ground to an angle of 55°, and truncated so as to clear the root of the thread, are distributed as follows: (*i.*) Two are fixed on the lower jaw of the gauge, so that the distance between them is an exact number of threads, representing twice the length of screw contained in a standard nut of corresponding diameter. (*ii.*) The third is fixed on the upper jaw midway between the two points on the lower jaw, and the three points are set to a standard male gauge having correct pitch, and the maximum effective diameter allowed. Opposite the single point is fixed the flat face *a*, which is adjusted so that the small cylinder *c* of such a diameter that it will touch the thread about half-way down its depth—will just enter the thread of a bolt made to the minimum effective diameter allowed.

Then, in testing, if the bolt enters the gauge and the "not go" cylinder refuses to enter the thread, the bolt is within the limits for pitch and effective diameter laid down in the tables, while any error in pitch which may be present will be duly compensated by a reduction in the effective diameter. With this gauge a "go" and "not go" ring gauge is used for the full diameter, and a "go" and "not go" snap gauge for the core diameter. With a complete ring gauge for the "go" gauge "not go" gauges are required if the checking is to be complete for the full, core, and effective diameters. In practice it is generally considered sufficient to use a "go" ring and a "not go" full diameter gauge, though this opens the door to the employment of thin threads. It should be remarked here that a "not go" screw ring is a useless and misleading gauge; it is difficult and costly to construct; it may tell you no doubt that the screw is wrong and ought to be rejected, but it affords no information as to what element in its form causes the rejection.

Up to the present no firm has undertaken the manufacture of the three-point pitch and effective diameter gauges, and they have not come into general use; they suffer also from the disadvantage that the wear is taken on the points, and even if these are properly hardened the life cannot be long.

It is easier to gauge a hole, for in this case the gauges are plugs. A complete plug gauge is required as a "go" gauge, and, to be strict, three "not go" gauges for the core, full, and effective diameters. For the core the "not go" gauge is a simple plain plug of appropriate size. For the full and effective diameters we use two screw gauges, each having a single turn of the thread; the first has a very thin deep thread, cut away on the slopes and at the root, so as to bear only on its crest, while the second is cut away at the crest and root, and bears on the slopes; the diameters are in each case of appropriate size, and the screw is rejected if either gauge enters appreciably. If a "not go" core diameter gauge only is used, holes with thin threads, in which the effective diameter and probably the full diameters are too large, will be accepted.

We pass next to the tolerances on the gauges and the means of checking these; the last is closely connected with the methods of production and has recently been discussed in a memorandum, "Notes on Screw Gauges,"† issued in February, 1916, from the National Physical Laboratory. In the case of a plug gauge, if a satisfactory ring check is available, the first step will normally be to try it with this. If it fails to enter it is usually rejected, but further examination is made to see to what particular the failure is due. If it enters examination is still necessary to determine whether it is up to size in all its elements; it may have an excessive pitch error which is compensated for by a large reduction in its effective diameter, and in this case it is useless as a gauge. Thus in nearly all cases measurement is required.

For the full diameter a micrometer or some simple form of measuring machine is all that is needed. The principle involved in the measurement of the effective and core diameters is shown in Fig. 8.

For the effective diameter, three small circular cylinders—three carefully selected needles of known diameter—are inserted, as shown in the thread, and a micrometer reading is taken over these; the mean diameter of the needles is determined by measuring them when suspended against a cylinder of known dimensions, and from these two readings the effective diameter can be calculated.

Instead of a plain cylinder we may employ a cylinder having a circular V groove, with an angle of 55° cut in it to a suitable depth. This is tested by means of two accurate cylinders, and its effective diameter is found as though it were part of a screw thread; the method of using it as a reference bar is obvious.

For the core diameter, the circular needles are replaced by three bars of triangular section, the angle at the apex being considerably less than that of the screw; measurements are taken with the micrometer—(1) with the bars against a cylinder of known diameter; (2) with the bars in the thread, and the core diameter is thus found.

To carry out these measurements rapidly at the laboratory, an instrument is employed in which the screw to be measured is held between suitable centres. A light carriage supporting two micrometers can move on balls either parallel to or at right angles to the axis of the screw; the axes of the micrometers are in the same plane as and at right angles to that of the screw. To measure the full diameter a standard screw is placed between the centres, and one micrometer A is set to some convenient mark; the other B is then adjusted until the standard screw is just held between the micrometers; the pres-

* The Committee and the engineering industry owe much to Mr. W. Taylor, of Messrs. Taylor, Taylor, & Hobson, for his work in this connection.

† To be obtained from Mr. W. F. Parrott, The Causeway, Teddington, or through the Engineering Standards Committee.

sure required for this should be very light, as the screw is easily deformed. Micrometer A is then withdrawn, the standard screw removed, and the screw to be examined put in place. This screw is then measured, using micrometer A. The difference in readings of A then gives directly the error in the full diameter of the screw. The diameters of most of the screw gauges tested at the laboratory are thus measured.

Turning now to the measurement of pitch, we notice first that pitch error may be of two kinds:—(*a*) A progressive error, increasing regularly as we go along the screw; and (*b*) superposed in many cases on this a periodic error, depending frequently on some want of adjustment in the leading screw of the lathe on which the thread was cut. Examples of these errors will be given later. In measuring the pitch of a screw, it is mounted on centres on a stiff bed which carries a saddle sliding parallel to the line of centres. This saddle is moved by a screw which has been carefully calibrated, and the motion is read on a large micrometer head. In its simplest form the saddle carries a pointer accurately ground to an angle of 55° with its axis at right angles to that of the screw. The pointer can slide in the direction of its own length on the saddle. The pointer is set by the micrometer with its two edges in contact with the sides of a thread and a reading taken. It is then withdrawn, the micrometer is turned until the pointer is opposite the next thread, when it is again adjusted, and so on. A series of readings taken thus give the distances between the consecutive roots of the thread, *i.e.*, the pitch, and from these the pitch error is calculated. The method is clearly slow and not very accurate; it is difficult to set the pointer. The method in use at the laboratory is as follows:—

The screw is mounted as before, but the feeler carried by

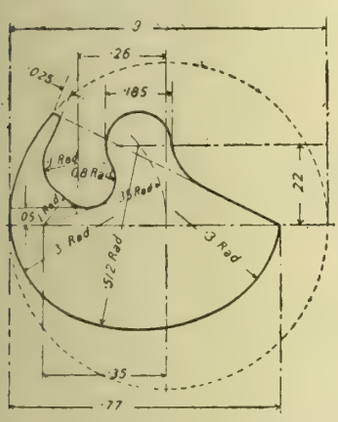


FIG. 10.

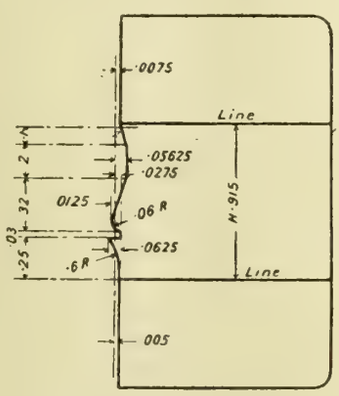


FIG. 11.

the saddle takes the form of a small spherical ball at the end of a bent lever. The ball is held pressed into the threads of the screw by a light spring, and as the saddle is traversed along the ball moves to and fro, always remaining in contact with the screw. The ball is too large in diameter to reach the bottom of the thread. In its motion it slides down one flank of the thread until it is arrested by contact with the opposite flank, when it immediately begins to move up this flank; this change of motion is very sharply defined. By noting on the micrometer screw the positions of the slider at which these changes of motion take place, we clearly have a means of measuring the pitch of the screw. To effect this a mirror is attached to the arm carrying the small sphere and rotates backwards and forwards as the arm moves. A spot of light reflected from the mirror on to a scale moves in one direction, then stops and moves back; after a time its motion is again reversed, and so on. The sharp reversals caused by the point of contact of the sphere passing from one flank of the screw to the opposite flank are clearly defined, and by their means an accurate measure of the pitch is obtained.

To measure the angle and form of a thread a microscope is most conveniently used. The microscope is fitted with cross wires and can rotate about its axis. Some means of measuring this rotation is required. Means also for bringing the part of the screw to be examined, and for focussing, are required, and care must be taken that the light which enters the microscope may come along the rake of the thread. The axis of the microscope is set at right angles to that of the screw. Fig. 9 shows a simple apparatus devised at the laboratory for this measurement.

To make a measurement of the angle, the microscope is first focussed on one of the centres which carry the screw; it is then moved aside and the screw is put in position and traversed by means of the adjustments until in the field of view. This method of focussing ensures that an axial section of the screw is under examination. The microscope is then rotated about its axis until the cross wire is along the flank of one of the threads and a reading is taken; the tube is turned and the screw traversed until the cross wire lies along the opposite flank, and a reading is again taken; the difference between these gives the angle of the screw. By setting the cross wire to run along the crests of the thread and taking a reading the squareness of the threads to the axis can be verified, while the general shape of the thread is obvious to the eye. By attaching the part carrying the screw to two slides at right angles, one parallel to and the other at right angles to the axis of the screws, fitted with accurate micrometers, measurements of the diameters and pitch of a small screw may be made.

In many cases, however, observations on angle and form can be made most readily by a projection apparatus. The screw is suitably mounted and illuminated by the aid of a small arc lamp and condenser. Carefully arranged lenses throw a magnified image on a screen, and observations are made on this image. The lenses must be chosen to produce uniform magnification over the field and there must be absence of distortion. At the laboratory lenses to secure this have been obtained, and the method has proved rapid and of great value. A magnification of 50 has been selected; the screen carries an accurate drawing of a section of the screw 50 times actual size. It is easy to compare the image formed with this correct profile. The screen carries adjustments which serve to bring the image and the drawing readily into coincidence.

Another method of comparison is to project simultaneously the image of an accurate screw placed alongside the one under examination; the differences are readily apparent.

The checking of screwed ring gauges is more difficult. Direct measurement is only possible if they are of considerable diameter. Means have been devised, provided the ring is not too small, and, where the information is specially required, are employed for measuring the diameters by the aid of small spheres, fitting into the threads, and internal micrometers. In general, however, check gauges are resorted to, the Taylor system being employed whenever real accuracy is desired. This in itself does not give a measurement of the diameter, but it is generally possible by the use of a sufficient number of checks of slightly different sizes to form a close estimate of the limits within which it lies. A simple and rapid method of measuring internal diameters, especially of small screws, is much to be desired.

III. *Form and Position Gauges.*—These, which are often extremely difficult to make, to measure and to check, perhaps hardly come within the category of limit gauges. In the case of plate form gauges the examination can sometimes be done readily by measurement, but check gauges are usually necessary, and the observation is made by bringing the two into contact on a plate of glass and holding them up to the light. The eye can readily detect a want of fit; to say exactly what is wrong is more difficult, *e.g.*, in the case of an elaborate band gauge for a shell. We have found the difficulty best met by the supply to the maker of an accurate check in addition to the drawing. More recently the projection apparatus employed for checking the form of a screw thread has been freely used and has given good results. Figs 10 and 11 show some examples of such profile gauges.

Position gauges, again, need checks for their verification, and the design and manufacture of these often present difficulties. The check is clearly an accurate replica of the part which it is intended to gauge, made, however, in a form which lends itself to exact measurement so that its accuracy may be secured. The details of measurement will differ for each gauge and no general account can be given.

Limit gauging is a wide field to discuss, and in this hasty survey the fringe has only been touched. The experience of the past year has shown its importance, and when once this was realised and the fact that accuracy was essential was grasped, British manufacturers have risen to the occasion and may be proud of the output of beautiful gauges now being passed into munition works.

INSTITUTE OF METALS.

At the autumn meeting of the Institute of Metals, held in London, on September 20th, a number of interesting papers were read and discussed, summaries of which are presented as follows:—

The Development of the Spelter Industry.—This paper, by Ernest A. Smith, A.R.S.M., M.I.M.E., is an interesting monograph on zinc, and deals with its history, methods of production, and industrial applications, and the present status of the zinc industry. The subject is dealt with under the following heads: Historical note; Progress of the European zinc industry; Progress of the American zinc industry; The Asiatic zinc industry; Present-day zinc smelting centres and output of spelter; The zinc market; The Spelter Convention; Ores of zinc; European sources of zinc ores; American sources of zinc ores; Asiatic and other sources of zinc ores; The European zinc ore trade; The metallurgy of zinc; Treatment of zinc-bearing complex ores; Smelting zinc-bearing complex ores; Electric smelting of zinc ores; Hydro-metallurgical processes of zinc extraction; Industrial applications of zinc; Future of the zinc industry. In tracing the development of the spelter industry from its commencement in the 16th century, attention is drawn to the steady growth of the industry on the Continent during the last century. Germany, taking advantage of her natural resources in zinc ore and coal, early took the lead as the largest producer not only in Europe, but in the world. For many years Germany remained the chief zinc producer, but in recent years very rapid strides have been made in zinc smelting in America, which now takes first place as the largest producer. Tables are given showing the status of the world's zinc industry, prior to the war, the figures giving the production and consumption of spelter in all the principal countries for ten years ending 1913, and also the average price in the London market. Reference is made to the Spelter Convention, which has hitherto largely controlled the output and price of zinc. In dealing with the ores of zinc attention is drawn to zinc concentrates which now form so important a source of the metal, and the successful smelting of which has caused considerable difficulty in the distillation process. The various electric furnaces for zinc smelting and the hydro-metallurgical processes of zinc extraction are briefly described. The industrial uses of zinc are considered in detail, special attention being given to the zinc alloys. In this connection the author considers that the extension of the uses of zinc in the future will be dependent in no small degree on the discovery of new alloys suitable for industrial purposes. With regard to the future of the spelter industry the author draws attention to the efforts that are now being made to increase the smelting capacity of the works in this country and in Australia, so that they may deal satisfactorily with the large quantities of zinc ore found within the British Empire.

Annealing of Arsenical Brass. — A paper, by C. H. Mathewson and E. M. Thalheimer (Yale University, U.S.A.) entitled "The Annealing of Arsenical Brass Containing 61 per cent. and 62·5 per cent. of Copper: A Study of the Structure and Properties Developed by Varying the Rate of Cooling Within the Transformation Range," was presented. During the summer of 1914 the authors were called upon to make tests for the purpose of selecting a brass mixture based upon the use of Copper Range copper—a "Lake" brand containing about 0·3 per cent. of arsenic—and of specifying forms of heat treatment which would give satisfaction in the manufacture of heavy tube. The particular process for which this material was intended consists essentially in hot-rolling a thick cake to a circular disc about ½in. thick, annealing and then cupping the disc, after which tube is produced by a number of closing-in and drawing operations, each preceded by annealing treatment. It is thus apparent that the material must be adapted to hot working, and, in addition, must possess a high order of ductility when cold, so that it may flow freely between the punch and die. As a result of preliminary tests on several mixtures, the authors recommended material containing 62·5 per cent. of copper, which, as ordinarily cast from Copper Range copper, would contain not more than 0·16 per cent. of arsenic. Using a high grade of spelter there would be no difficulty in hot-rolling brass containing a considerably higher percentage of copper than this. It is their impression that the hot-rolling properties of these alloys are largely dependent upon the lead-content and the amount of the Beta constituent present at the rolling heat. The main purpose of this paper is to present the results of tests which show comparisons between the properties of brass containing (1) 62·5 per cent. of copper and very little arsenic (0·024 per cent.), (2) 62·5 per cent. of copper and considerable arsenic (0·120 per cent.), and (3) 61 per cent. of copper and considerable arsenic (0·139 per cent.) after different forms of heat treatment. In general, it may be said that brass of this character made from arsenical copper is likely to afford a better combination of strength and ductility than metal made from electrolytic copper when both are properly annealed. The authors are convinced that arsenical brass of this type will meet severe hot- and cold-working requirements. With regard to heat treatment, it is agreed that, in order to obtain the most favourable conditions for cold-working a brass containing 61 per cent. of copper (and this probably applies to ordinary Muntz metal containing 60 per cent. of copper), annealing, if conducted at temperatures above moderate red heat, should be followed by at least a moderately slow rate of cooling, say, 20° C. per minute, and slow cooling should be continued to a temperature not far above 450° C. If the metal is higher in copper, viz., if it contains some 62 per cent. to 63 per cent. of copper, emphasis should be laid on very slow cooling; for example, a 5° rate is far more satisfactory than a 20° rate, and in such case the metal should be allowed to cool normally to some 550° C., whereupon it may be quenched in a stream of water if desired. In case a rate of cooling in excess of 20° C. per minute prevails, it will be advantageous to allow such cooling to proceed unchecked to 450° C., or even a lower temperature.

Cadmium in Spelter.—In view of the importance of brass to the cartridge-case maker the latter has to take every precaution that his alloy is pure. Cadmium is one of the impurities that has to be guarded against. It occurs in most samples of spelter to a greater or lesser extent. In his note on this subject before the Institute of Metals, Mr. W. R. Ingalls (U.S.A.) makes the interesting statement that the electrolytic process of zinc extraction affords an easy means for the separation of cadmium. He says that it should be borne distinctly in mind that the electrolytic process is going to be commercially applicable only under some specially favourable conditions, and is not going to drive zinc smelting out of the world's arts. However, the electrolytic zinc production that is likely to endure should go a long way toward meeting the demand for high-grade spelter, and especially for spelter low in cadmium. It appears that a good deal of the high-grade and intermediate spelter that America has sold to Great Britain at fancy prices during the last 18 months has been redistilled common spelter. Mr. Ingalls suggests that Great Britain ought to have bought common spelter and redistilled it herself.

The Allotropy of Silver.—In his paper on "The Allotropy of Silver," Dr. W. D. Helderman, of Utrecht University, presents both an historical monograph and a record of experimental work. Using for the latter the dilatometer and the pycnometer he comes to the following four conclusions: (1) Silver has a transition point at about 77°; (2) pure silver consists of (at least) three allotropic (enantiotropic) forms; (3) all objects made of silver are in a mestable condition as a result of the retardation in the transition of the altered form; (4) all physical constants of silver (excepting the atomic weight) refer to indefinite mixtures of the different allotropic forms. New experiments are wanted to obtain constants for the different forms of silver in a pure state.

American Shipbuilding.—Steel merchant vessels were building, or under contract to be built, in American private shipyards at the commencement of July 1st, to the number of 385, of an aggregate displacement of 1,225,784 tons. The Senate Naval Committee has reported the Naval Appropriation Bill, which provides for the largest naval building programme in American history. The new battle-ships, battle cruisers, scout cruisers, and other types of warships and auxiliaries proposed to be built number 157, with an approximate displacement of 855,000 tons. The building of these vessels will involve an aggregate estimated outlay of 588 million dollars.

A COMPACT DESIGN OF AIR COMPRESSOR.

WE illustrate herewith a design of air compressor in which the compression is effected in three or more stages, the joint invention of Mr. William Reavell and Mr. E. W. Jones, Ranelagh Works, Ipswich. The compressor has been designed with a view to make it more compact and require less head room than ordinary types. Figs. 1 and 2 are vertical sections of the compressor taken at right angles to each other, Fig. 3 is a section on the line Z Fig. 1, Fig. 4 a plan of the head of the compressor with the cover removed, and Fig. 5 a detail view illustrating the flexible connection between the high-pressure piston and the bridle piece or frame.

The main cylinder A is of two diameters and is fitted with a trunk piston B reciprocated by a connecting rod C the

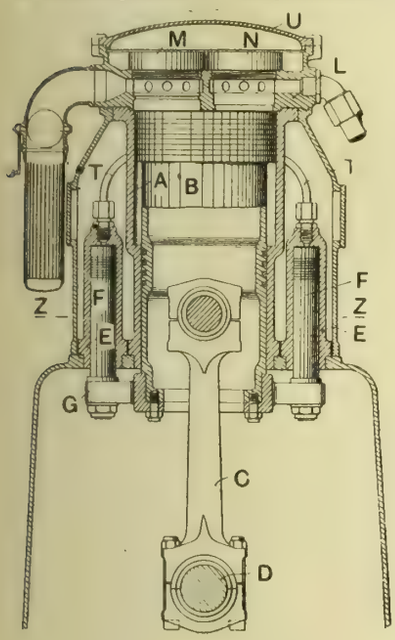


FIG. 1.

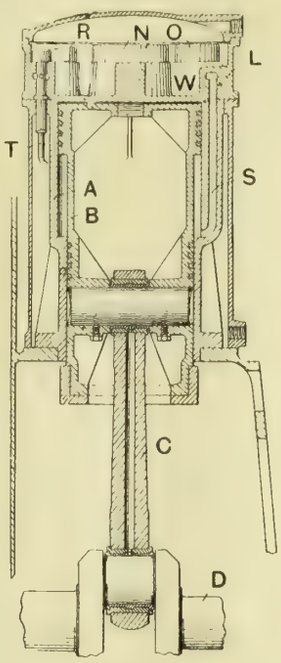


FIG. 2.

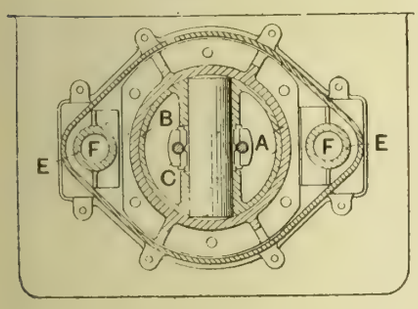


FIG. 3.

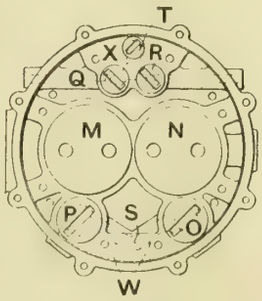


FIG. 4.

REAVELL'S AIR COMPRESSOR.

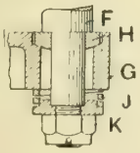


FIG. 5.

gudgeon pin of which is above the lower end of the piston and a crankshaft D which may be an extension of the crankshaft of a Diesel engine; the first stage of compression is effected above the piston head and the second stage below the piston head in the annular space formed between the larger diameter of the cylinder and the smaller diameter of the trunk portion of the piston. A pair of high-pressure cylinders E are disposed at opposite sides of and parallel to the main cylinder A. The cylinders E are fitted with pistons F that are flexibly connected to the arms of a bridle piece or frame G that is rigidly attached to the lower end of the trunk piston B as shown. In one method of connecting each piston F to its bridle arm, the lower end of the piston as shown in Fig. 5 is reduced and extends through a partly spherical washer H mounted in the enlarged and correspondingly shaped upper end of an opening in the bridle arm, the piston being tightly held in position but with sufficient freedom to take its true alignment in the cylinder by means of a coiled spring J compressed against the underside of the bridle arm by a nut. All the valves are located in the casting L forming the main cylinder cover, the several valves being arranged as seen clearly in Fig. 4, M and N being the low pressure inlet and outlet valves respectively, O the intermediate-pressure inlet valve to which air is led from the outlet valve N through the first stage inter cooler (not shown), P the intermediate pressure outlet valve, Q the high pressure inlet valve to which air is led from the valve P through the second stage inter cooler (not shown), and R the high pressure outlet or delivery valve. The valves O and P control the passage of air to and from a chamber W that is in free communication with the bottom of the larger part of the cylinder A through a passage S, Figs. 2 and 4; and the valves Q and R control the passage of air to and from a chamber X that is in free communication with both cylinders E through a bifurcated pipe connection T, Figs. 1, 2, and 4. The passage S and its connected valve chamber W form part of the annular second-stage compression space and the pipe connection T and its connected valve chamber X form part of the third-stage compression spaces, so that the swept volume of these compression spaces has to be proportioned accordingly. The cylinders A and E are contained in a cooling water jacket which is in communication with cooling water spaces in the casting L, which is provided with a cover.

FUEL ECONOMY.

FIRST REPORT OF COMMITTEE APPOINTED BY THE BRITISH ASSOCIATION.

AT the recent meeting of the British Association at Newcastle-upon-Tyne the first report of the committee appointed for the Investigation of Fuel Economy, the Utilisation of Coal, and Smoke Prevention, was presented. The committee consists of Prof. W. A. Bone* (chairman), Mr. E. D. Simon* (secretary), the Right Hon. Lord Allerton,* Mr. Robert Armitage, Prof. J. O. Arnold, Mr. J. A. F. Aspinall, Mr. A. H. Barker, Prof. P. P. Bedson, Sir G. T. Beilby,* Sir Hugh Bell,* Mr. E. Bury, Dr. Charles Carpenter,* Dr. Dugald Clerk,* Prof. H. B. Dixon, Dr. J. T. Dunn,* Mr. S. Z. de Ferranti, Dr. William Galloway, Prof. W. W. Haldane Gee, Prof. Thos. Gray, Mr. T. Y. Greener,* Sir Robert Hadfield,* Dr. H. S. Hele-Shaw,* Mr. D. H. Helps, Mr. Greville Jones, Mr. W. W. Lackie, Mr. Michael Longridge, Dr. J. W. Mellor, Mr. C. H. Merz,* Mr. Robert Mond,* Mr. Bernard Moore, Hon. Sir Charles Parsons,* Sir Richard Redmayne,* Prof. Ripper, Prof. L. T. O'Shea, Mr. R. P. Sloan, Dr. J. E. Stead,* Dr. A. Strahan,* Mr. C. E. Stromeyer, Mr. Benjamin Talbot, Prof. R. Threlfall, Mr. G. Blake Walker, Dr. R. V. Wheeler, Mr. B. W. Winder, Mr. W. B. Woodhouse, Prof. W. P. Wynne, Mr. H. James Yates,* and their report is as follows:—

The national aspects of fuel economy may be considered from two somewhat different standpoints, namely (1) in view of the economic situation created by the war, which will necessitate the general adoption of more scientific methods in the future development and utilisation of the nation's mineral reserves, and (2) in view of that remoter, but possibly not far distant, future when our available coal supplies will be restricted by approaching exhaustion. In approaching its task the Committee decided that it could best serve the national interest by concentrating its attention upon the more immediate aspect of the problem.

It can hardly be questioned that the chief material basis of the great industrial and commercial expansion of this country during the past century has been its abundant supplies of easily obtainable coal, which, until recent years, has given us a position of advantage over all other countries. It is also equally true that we can no longer claim any advantage in this respect over our two closest competitors.

There can be little doubt but that up to the present we have been wasteful and improvident in regard to our methods of getting and utilising coal, and that not only are great economies in both these directions attainable, but also that the question of the general adoption of more scientific methods in regard to these matters is one of vital importance, in view

* Denotes a member of the Executive Committee.

of the trying period of economic recuperation which will immediately succeed the war.

For some years before the war the average price of coal at the pithead had been decidedly on the up-grade, owing chiefly to deeper workings, higher wages, and greater precautions for ensuring the safety of the mines. The result of the great coal strike in 1912, and the legislation which it provoked, was to accentuate this tendency. And if, as seems probable, prices continue to rise for some time after the war at an accelerated rate, as compared with the pre-war period, the question of the best utilisation of fuels will be of increasing importance to the nation.

According to the report upon the World's Coal Resources, issued by the International Geological Congress in the year 1913, the geographical distribution of the world's total possible and probable reserves of coal of all kinds available within 6,000ft. of the surface amounts in all to 7,397,553 million metric tons. The fact that the available reserves of coal in Great Britain only amount to about one-fortieth, whilst those of the whole Empire do not amount to more than about one-fourth, of the world's estimated total, is one which ought to be brought home to everyone responsible for the economic development of our national and imperial resources, especially in view of the fact that the United States, whose competition in the immediate future will probably be much more severely felt than ever before, possess more than half the estimated world's coal, and that also in regard to the two prime considerations of quality and cost of production the States probably compare favourably with Great Britain and the Empire.

Moreover, it may be pointed out that in the United States both the Government and the University of Illinois have, for some years past, conducted numerous important chemical investigations and large-scale trials upon the character of the principal American coal seams and their adaptation for various economic ends, and that, in consequence, American manufacturers have at their disposal much more complete and systematic information about their country's coal resources than is at present possessed by their British competitors. Also, the United States Government, which is continually extending its policy of the conservation of its natural resources, has already taken legislative steps to prevent the premature exploitation of the coalfields of Alaska. Nor has Canada lagged behind her neighbour, as is proved by the recent exhaustive "Investigation of the Coals of Canada with reference to their Economic Qualities," conducted at the McGill University, Montreal, under the authority of the Dominion Government, and published in the years 1912 and 1913 by the Department of Mines in six imposing volumes. No such comprehensive investigations have ever been undertaken in this country, where they are much needed. The Committee is of opinion that the example of the United States and Canada might be followed with advantage to the industrial community by the Government of Great Britain, and that representations should be made with the object of inducing the Government to provide adequate funds in aid of further researches and investigations upon the chemical character of the principal British coal seams, the best means for their future development in the national interest, and upon problems of fuel economy, including the utilisation of all the by-products obtainable from coal.

The rapid increase during recent years in the world's demands for coal is shown by the following approximate figures covering the ten years' period immediately preceding the outbreak of war: —

Year.	Approximate Total. Millions of Tons.
1903	800
1908	1,000
1913	1,250

From these figures it would appear that, during the period in question, the world's demands have continuously increased at a compound interest rate of nearly 5 per cent. per annum. Another important fact is that these demands have been principally met by three countries, namely, the United States, Great Britain, and Germany, which, between them, have hitherto annually raised 83 per cent. of the total anthracite and bituminous coals consumed in the world. This being so, it is of interest to compare the relative rates of increase in the coal productions of these three countries during recent years, which may best be deduced from a comparison of quinquennial averages over a period of 15 years, from 1900-1914 inclusive, as in Table I.: —

TABLE I.—*Coal Productions of the United States, Great Britain, and Germany—Quinquennial Averages.* 1900 *to* 1914.

Period.	Millions of tons per annum.		
	United States.	Great Britain.	Germany.*
1900-04	288·2	226·8	112·5
1905-09	400·5	256·0	139·8
1910-14	519·2	269·9	168·3

* Excluding lignites and brown coals.

From these figures it may be inferred that up to the outbreak of the war the coal output of the United States was increasing annually at a compound interest rate of about 6 per cent., that of Germany at a compound rate of about 4 per cent., whilst the British output was increasing at a compound rate of 2 per cent. only. During the period 1910-14 the United States produced nearly twice as much coal as Great Britain, and, assuming that these relative rates of increase are maintained after the war, it may be predicted that Germany's output of coal will overtake that of Great Britain about 20 years hence, when each country will be producing some 420,000,000 tons per annum.

The public cannot be too often reminded that not only is coal of prime importance as a fuel, but also that, when suitably handled by the chemist, it yields very valuable by-products, which are the raw materials of important industries. Thus from coal-tar, and other by-products of its distillation, are obtained the raw materials for the manufacture of both synthetic dyes and drugs and certain high explosives. Another important by-product obtainable is ammonia in the form of sulphate, which is chiefly used as a fertiliser in the production of foodstuffs. The use of artificial fertilisers, including ammonium sulphate, by agriculturists in Great Britain is still in its infancy, and the near future ought to see a large expansion in the home demands for nitrogenous fertilisers.

Among other products obtainable by the low-temperature distillation of coal are liquid hydrocarbons of the paraffin and naphthene series, and it is probable that large quantities of "motor spirit" could be manufactured in this country from coal. There is no doubt that we in this country have not been sufficiently alive to the importance of recovering such by-products from the raw coal raised in our mines, and that we have been very much behind Germany in this respect. Thus, for example, whilst in the coking industry modern by-product recovery plants had been universally installed years ago throughout Germany, we were, in 1913, still carbonising about six and a half million tons of coal annually for metallurgical coke in old-fashioned beehive ovens. Also, whereas our total production of ammonium sulphate from coal was in 1913 about 318,000 tons, Germany produced nearly half a million tons from a very much smaller output of coal.

The community needs to be reminded that, at least so far as this country is concerned, progress in fuel economy involves something more than increased thermal efficiency in respect of power production and of heating operations generally, important as these undoubtedly are. It also involves the whole question of the better utilisation of our coal, including the recovery of by-products and the consequent abolition of the smoke nuisance, which, at present, directly and indirectly, costs the country many millions of pounds per annum.

TABLE II.—*Coal Production in Great Britain—Quinquennial Averages,* 1870 *to* 1914—*Millions of Tons per Annum.*

Period.	Average output.	Calculated at 2 per cent. compound interest.	Proportion of total output exported.
1870-74	121·5	121·5	0·13
1875-79	133·6	131·1	0·146
1880-84	156·4	148·1	0·172
1885-89	165·2	163·5	0·200
1890-94	180·3	180·5	0·220
1895-99	202·0	199·3	0·237
1900-04	226·8	220·1	0·27
1905-09	256·0	243·0	0·31
1910-14	269·9	268·2	0·326

There are two outstanding features in the history of the British coal trade to which the Committee desires to draw

attention. One is the remarkably steady increase in the total output of our mines, which, since 1870, has been maintained at an almost uniform compound interest rate of 2 per cent. per annum, as Table II., giving quinquennial averages over a period of 45 years (1870-1914) shows.

The second feature is the phenomenal growth of our export trade, which, during the past 60 years, has increased something like 20-fold, both as regards the quantities and the values of coal exported. Moreover, its value relative to other values exported has, during the same period, increased fourfold, until at the outbreak of war it constituted about 10 per cent. of our total exported values. We were then actually transacting over 70 per cent. of the total sea-borne coal trade of the world. It must, however, be borne in mind that a considerable proportion of the exported coal supplies the needs of our mercantile marine.

Another circumstance which demands attention is the fact that the proportion of the coal raised annually in the United Kingdom which is exported has been doubled within the past 35 years, trebled within half a century, and is still increasing. Three factors have operated in producing this result. One is the proximity of the finest coalfields to our ports, another is the increased demands for coal from Europe and South America, while a third has been the phenomenal growth of our mercantile marine.

The foregoing figures for the total outputs of our mines by no means represent the real rate of depletion of our available coal reserves. A vast amount of usable coal is left behind in the mine because, under present individualistic conditions, it does not pay to bring it to the surface. A larger profit on the capital of a colliery company can often be earned by working the better classes of coal and leaving the less valuable grades underground. According to figures issued in the Report of the 1905 Royal Commission on Coal Supplies, this wastage amounted to nearly 25 per cent. of the total raised in the larger coalfields. The question of checking this wastage by finding out in what ways the less valuable grades can be turned to good account commercially is one of supreme national importance, and the Committee desires to draw special attention to it. Much of the coal now left behind in the mines ought to be converted into useful forms of energy and products for public purposes, and one of the most important aspects of the fuel-economy problem in Great Britain is the devising and organising of means for making it possible to raise this hitherto wasted coal at an economic advantage.

So much for the general statistics of coal production. Coming now to the possible saving in the coal consumed annually in this country at the outbreak of the war (nearly 200,000,000 tons), it will be remembered that the 1905 Royal Commission on Coal Supplies found that the possible saving in our then annual coal consumption (167,000,000 tons) amounted to between 40 and 60 million tons. There are many competent judges who consider that, notwithstanding the improved apparatus which has been put into use in the best factories throughout the country during the last ten years, the average result obtained for the country as a whole still lags behind the best obtainable to-day in as great a proportion as it did in 1905. It will be the business of this Committee (1) to estimate as nearly as may be the present possible margin of saving, and (2) to point out the particular directions in which it can be attained from a national point of view.

Having regard to the magnitude of its work, and the fact that the coal question is one upon which almost every branch of manufacturing and transport industry is dependent, the original Committee of 13 members appointed by the Association in October, 1915, decided to exercise somewhat freely its powers of co-option, so as to make a General Committee sufficiently large and representative of all the important interests involved.

For the more detailed and special study of particular aspects of the fuel question the enlarged General Committee resolved itself into the following five Sub-Committees, each of which subsequently elected its own chairman, and, subject to its reporting from time to time to the General Committee, proceeded to make such arrangements as seemed best for the prosecution of its work:—

(*a*) Chemical and statistical.
(*b*) Carbonisation.
(*c*) Metallurgical, ceramic, and refractory materials.
(*d*) Power and steam raising.
(*e*) Domestic heating and smoke prevention.

The General Committee next appointed an Executive Committee, composed of the chairman and secretary of the General Committee, the chairman of each Sub-Committee (ex officio), and 12 other members, which could meet frequently in London for the discussion of matters relative to the organisation and co-ordination of the work of the Committee as a whole, to deal with matters arising out of the proceedings of the Sub-Committees which might require immediate action or decision, and to receive and consider communications either from Government Departments or Technical Associations concerning subjects under investigation by the Committee.

The General Committee has met in London four times since its appointment in October, 1915, the various Sub-Committees have each met about four times since their formation in January, 1916, whilst the Executive Committee has met regularly on alternate Fridays since April 28th last. In all, 30 meetings have been held during the year.

At the first meeting of the General Committee it was decided to organise a series of conferences of manufacturers and others interested in the fuel question in a number of the larger industrial centres, for the purposes of arousing interest in the work of the Committee, of inviting co-operation and suggestions from large users of fuel, and of educating public opinion in respect of the national importance of the question. Six conferences have already been held, as indicated in Table III.:—

TABLE III.

Date.	Place.	Under the auspices of
1915.		
November 19..	Stoke-on-Trent ..	English Ceramic Society. North Staffs Mining Institute.
1916.		
March 6	London	London Section of the Society of Chemical Industry.
March 13	Middlesbrough	Cleveland Institution of Engineers.
March 29	Nottingham	Nottingham Section of the Society of Chemical Industry.
April 5	Manchester	Manchester Section of the Society of Chemical Industry.
April 6	Sheffield	Sheffield Society of Engineers and Metallurgists.

All but one of the meetings were addressed by the chairman and one or more of the other members of the Committee, and the discussions which invariably followed were productive of valuable suggestions or information regarding local conditions which demand special consideration. It may be also mentioned that the chairman lectured at the Royal Institution of Great Britain, on Thursdays, January 20th, 27th, and February 3rd last, on "The Utilisation of the Energy of Coal."

In March last the Committee was asked by the newly-formed Central Coal and Coke Supplies Committee of the Board of Trade to make suggestions as to economies in fuel consumption which could be made at the present time, and, as the result of further correspondence upon the matter, it was arranged that Sir Richard Redmayne should act as the representative of the Board of Trade Committee on this Committee.

During the first year of its existence the attention of the Committee has been fully occupied with questions of organisation and a preliminary survey of the ground which must be explored later on. Already several important lines of investigation needing the co-operation of manufacturers have been instituted and are well in hand. But the returns are in most cases not yet sufficiently complete to justify publication in the report, and, in view of the importance of the interests and issues involved, the Committee feels that it would be premature to issue any detailed report on particular aspects of the fuel question until its enquiries have reached a more advanced stage than at present.

The Committee recommends that it be re-appointed to continue its investigations, as outlined and foreshadowed in this report, and, in view of the considerable expense involved in carrying out such work, it feels justified in asking for a grant of £100.

(To be continued.)

TRUING DEVICES FOR GRINDING WHEELS.

GRINDING wheels are in reality cutting tools revolving at high speed whereby countless sharp points remove minute chips by what we call, for want of a better term, the action of abrasion. In the strictest sense of the word this is not correct because the word abrasion means to wear or rub, whereas a modern grinding wheel actually removes material, be it hard or soft, by a cutting instead of a wearing action. To obtain the best results the innumerable cutting points on the surface of the grinding wheel should be kept sharp, and the periphery concentric with the spindle, otherwise the efficiency of the wheel is materially lowered. In the following article, by Mr. F. B. Jacobs, reproduced from "The Iron Age," a few simple methods of truing grinding wheels are briefly considered.

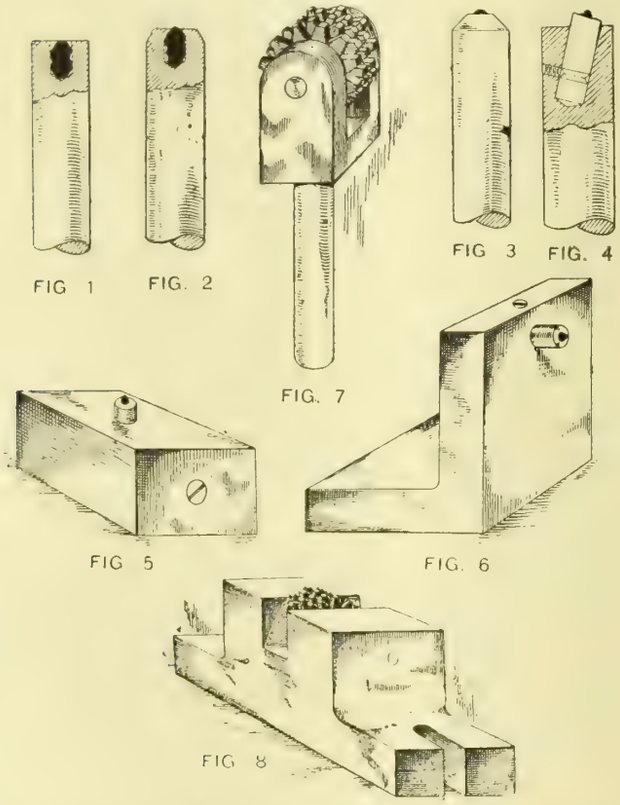


Fig. 1.—The diamond set in a hole in the end of a rod. Fig. 2.—The metal of the rod peined over the stone. Fig. 3.—The completed setting with the metal turned off. Fig. 4.—An arrangement employing an auxiliary plug capable of adjustment to bring a new cutting edge into action. Fig. 5.—Simple device for surface grinding machine wheels. Fig. 6. Arrangement for the wheels of small cutter grinding machines. Fig. 7. Grinding wheel dresser consisting of five cutters mounted in a holder and intended for use where it is desired merely to keep the wheel rough. Fig. 8.—Wheel truing device for large surface grinding machines.

The tools used for this purpose are of two kinds, diamonds and ordinary emery wheel dressers. There are two varieties of diamonds used, that is to say, bortz stones, which are nearly white in colour, and the darker variety called black diamonds. Bortz stones are comparatively inexpensive when compared with black diamonds, but they are not so hard and consequently are shorter lived. It is, therefore, more economical to buy black diamonds. Both varieties are sold by the carat, and can be bought loose or already mounted in steel or copper holders. The majority of manufacturers prefer to buy loose stones, as by this method flaws are more readily detected, and since these stones are never guaranteed it is important to see that only good specimens are selected.

The operation of setting the stones is comparatively simple, and can be entrusted to any tool-maker who has the reputation of being a careful workman. In setting a stone, all workmen do not proceed along the same lines, but the following method, which is used by many tool-makers, is simple and satisfactory. First select a drill of the same size as the stone. This is readily accomplished by passing the stone through the holes in an ordinary drill gauge. As stated before, both steel and copper holders are used, but in actual practice the latter makes the better holder for two reasons. First, it is very malleable, and thus is easily worked, and also copper is an excellent conductor of heat and readily absorbs superfluous heat, thereby tending to prevent overheating the stone, which often causes it to fracture. The rod should be about 6in. long, and of the correct diameter to fit the holder on the machine where it will be used, ½in. being a good diameter for the average-sized stone. A hole is drilled in the end of the rod deep enough to bury the stone, as shown in Fig. 1. The next step is to pein over the metal which holds the stone firmly in place. This is done with a light hammer and a small staking chisel, the result being shown in Fig. 2. Care should be exercised as a diamond is quite brittle and easily broken by a chance blow. The completed setting is shown in Fig. 3, the superfluous metal having been turned away. Some tool-makers prefer to braze the stone in position, and while this method no doubt holds the stone firmly in place, the heat necessary to melt the spelter is liable to crack the stone. However, as this method of brazing stones in place is often used by reliable manufacturers there certainly is some authority for employing it. The process consists of filling the hole about half-full of spelter and flux, and when it has reached a molten state the stone is pressed in place, which causes the spelter to rise in the hole, thus forming a matrix that grips the stone firmly. It may be well to add that the work should under no circumstances be cooled in water, as the sudden contraction of the diamond will, in many cases, cause it to fracture.

Even the hardest stones will wear flat in time. Thus it is necessary to reset them occasionally, which brings a new cutting edge in position. This is done by turning the stone upside down or canting it sideways. The holder shown in Fig. 4 accomplishes this end in a very simple manner. It consists of an auxiliary plug in which the stone is mounted, fitting in a hole the axis of which is at a slight angle with that of the main holder. The plug is held in place by a set-screw. When the stone becomes flattened the plug is turned slightly, which brings a new cutting edge in position. This device is covered by patents and it is not public property.

Care should be exercised while using a diamond as an undue strain caused by gouging it into the wheel often results in tearing the stone from its setting, in which event it is generally lost. In truing wheels on cylindrical grinding machines water should always be used to keep down frictional heat and several light cuts are to be preferred to a few heavy ones. It is hardly necessary to state that the tool should never be guided by the hands, as it is impossible to do a satisfactory job in this manner. Nearly all grinding machines are equipped with suitable holders to accommodate truing devices, and they should always be used. The device illustrated in Fig. 5 is excellent for truing wheels on surface-grinding machines. It is very simple, consisting of a diamond set in a holder 1½in. long, which is fastened in a block of cast iron by a set-screw. It can be held on a magnetic chuck or clamped in the vice. For truing wheels on various types of small cutter grinding machines an angle iron, as shown in Fig. 6, gives good results. The diamond holder is fastened by a set-screw, and the angle iron is clamped to the platen of the machine by a strap, bolt, or other convenient means.

We are sometimes inclined to look askance at ordinary emery wheel dressers in connection with wheels for precision grinding, but under certain limited conditions they are productive of excellent results. In ordinary cylindrical grinding it is customary to rough out several hundred pieces before taking any finishing cuts, and as we are removing stock only, paying absolutely no attention to finish, all that we desire is a fast-cutting wheel. In cases of this kind a few emery wheel cutters mounted in a holder, as shown in Fig. 7, will prove a revelation to the man who has never used them. They keep the wheel rough and free cutting, which is just the condition required. For truing the wheels used on large surface-grinding machines a holder, as shown in Fig. 8, will be found a valuable accessory. It should be provided with slots for clamping it in place. On a magnetic chuck, however, the force of the magnetism is sufficient to keep the holder in place. It must be borne in mind that cutters of this kind are practicable for roughing wheels only, but when we stop to consider that even a comparatively small diamond costs several dollars, whereas a set of emery wheel cutters can be purchased for a few cents, their merits are well worth consideration.

SCIENTIFIC AND INDUSTRIAL RESEARCH.

REPORT OF THE ADVISORY COUNCIL.

Previous Government Action in the Present Century.—Certain events which preceded the establishment of the Council are worthy of record because they are now seen to have a general significance which was not realised at the time. As early as 1900 the Government had taken an important step in the encouragement of organised scientific support for our trades and industries. The National Physical Laboratory was then established, with the assistance of a grant from the Treasury, under the control of the Royal Society, and opened in 1902 by His Majesty the King, then Prince of Wales. The Government made its first modest capital grant of £13,000 for the buildings and equipment of the laboratory, and an annual allowance for maintenance of £4,000 for five years. The laboratory has done and is doing most valuable work for our industries and for the Government, and it might have done much more had it been endowed with anything like the annual subvention of nearly £100,000 which the American Bureau of Standards receives for development and maintenance from the United States Government. But we think experience has shown that no single institution, however great or distinguished, can expect to do more than a part of all that our vast industries require.

Although not dealing with research in the strict meaning of the term, the work of the Engineering Standards Committee deserves mention in this connection because the Government early recognised its value, and because the Committee brought about co-operation of a valuable kind between the firms in the several branches of the industry and undoubtedly prepared the way for valuable research. The Treasury contributes to the expenses, and the Indian Government, which made a grant in 1903, pays for the cost of preparing reports on subjects affecting India.

Similarly, the Imperial Institute, established originally in order to co-ordinate and distribute information bearing on trade, has since undertaken scientific research related to industry. The Institute was founded in 1887 in honour of the Jubilee of Queen Victoria, but was reconstituted and transferred to the Government by Act of Parliament in 1902. But neither the Imperial Institute nor the National Physical Laboratory have experienced either the burden of work or the large subsidies which would have followed on a general recognition that their activities were necessary to the national welfare.

A further important stage in the realisation of the national needs was marked by the foundation in 1907, under a Royal Charter, of the Imperial College of Science and Technology, "to give the highest specialised instruction and to provide the fullest equipment for the most advanced training and research in various branches of science, especially in its application to industry." The Imperial College was in large part a national effort, for the Government transferred to the new College its own Royal College of Science and Royal School of Mines, together with an annual subsidy of £30,000 a year, and the Commissioners of the 1851 Exhibition made a large grant of land at South Kensington.

Yet the growth in the endowments, the income, the number of departments, and the students of this great foundation still left much to be done in other directions. Other machinery and additional State assistance were absolutely necessary in order to promote and organise scientific research with a view to its application to trade and industry, but it needed the shock of the great war to make the need manifest. The outbreak of war found us unable to produce at home many essential materials and articles. We were making less than a couple of dozen kinds of optical glass out of over a hundred made by our enemies. We could hardly make a tithe of the various dye-stuffs needed for our textile industries with an annual output worth over £250,000,000 a year. We were dependent on Germany for magnetos, for countless drugs and pharmaceutical preparations, even for the tungsten used by our great steel makers, and for the zinc smelted from the ores which our own Empire produced.

The Government Scheme.—When, in May, 1915, the Presidents of the Boards of Trade and of Education received a deputation from the Royal Society and other learned societies specially interested in the various branches of chemistry, urging "Government assistance for scientific research for industrial purposes, the establishment of closer relations between the manufacturers and scientific workers and teachers, and the establishment of a National Chemical Advisory Committee for these purposes," the two Presidents were in a position to announce that the Government had decided to establish machinery with wider powers than had been suggested, so as to make it possible to encourage research not only in chemical but in all other sciences affecting industry. A week later, in introducing the Board of Education estimates in the House of Commons, Mr. Pease announced the impending appointment of an Advisory Council specially entrusted with the supervision and encouragement of scientific research, particularly in relation to industry. On both occasions he explained that the Government intended to deal with this problem as an integral part of a comprehensive improvement in our educational system which the Board of Education had in prospect. In June the Liberal Government made way for the present Coalition Ministry, and in July the new President of the Board of Education, Mr. Arthur Henderson, issued a White Paper [Cd. 8005], describing the Government's "Scheme for the organisation and development of scientific and industrial research." The Order in Council already referred to, which established the Committee of the Privy Council for Scientific and Industrial Research and the Advisory Council, was issued on July 28th, and the Advisory Council met for the first time on August 17th, 1915. Since that date they have held 16 meetings, as well as numerous meetings of committees. The President, in the White Paper, had pointed out that the object of the Government was "to establish a permanent organisation for the promotion of industrial and scientific research," which would operate over the kingdom as a whole and utilise the most effective means to the end in view, irrespective of their locality. Since science and industry were both indifferent to political boundaries, a single fund for the good of the United Kingdom as a whole was entrusted to a single authority—a Special Committee of the Privy Council. The State had thus recognised the necessity for organising the national brain power in the interests of the nation at peace.

The Method of Approach.—The Council decided to give science in its applications to industry precedence over pure science in their deliberations. The Council realise that they have to deal with the practical business world, in whose eyes a real distinction seems to exist between pure and applied science. The average manufacturer is impressed with the importance of quick returns. He cannot afford to wait. Such quick-result enquiries as the manufacturer is induced to make are very likely to be fruitless and to reduce his enthusiasm for science still further. She finds too few suitors in our industries, for she is a mistress who reserves her favours for a complete and single-hearted devotion.

But there was another consideration which alone would have compelled the Council to begin with research of directly industrial application. The Universities, which are the natural homes of research in pure science, have been so depleted of both students and teachers by the war that they are barely able to continue their routine work, and can command at the moment neither the leisure nor the detachment of spirit that are essential conditions of original research. Enquiries we have recently made in the hope that we might be able to help individual investigators at the Universities to increase their output, have convinced us that any effective encouragement of research in pure science must await the return of peace.

How, then, were the Council to proceed? On the one hand, the war had greatly reduced the number of workers available for research of any kind. On the other, every consideration of urgency pointed to concentration on the field of industrial research, both as the best means of enlisting the co-operation of the manufacturers, without which no Government scheme could succeed, and as the quickest way of preparing for the trade conditions likely to arise after the war. In these circumstances the Council might have concentrated all their energies upon the rapid initiation of one or two far-reaching proposals likely to attract wide attention and designed to improve the outlook in one or other of our greatest industries. But the problems with which we have to deal are not susceptible of rapid and dramatic solution. The successful organisation

of research on a national scale is likely to take longer than the establishment of a good works laboratory—a long business at best. The only hopeful line of action appeared, therefore, to involve a period of careful enquiry and consultation, followed by a gradual and systematic attack upon a wide and carefully selected front.

(*a*) *Aid to Existing Researches.*—Our first enquiries showed that there were certain researches being conducted or directed by professional associations in the period preceding the war, which stood in grave jeopardy of enforced abandonment. These investigations had been paid for by the voluntary contributions of several great engineering and other professional societies, and thus carried with them the best guarantees of their necessity and effectiveness. The Council decided, therefore, to save as many of these derelict researches as possible, and accordingly recommended the payment of series of grants to the societies concerned.

(*b*) *Conferences with Professional and other Societies.*—The chairman and other officers of the Council have interviewed representatives not only of the Royal Society and the Chemical Society, but of all the principal engineering societies throughout Great Britain, and Prof. McClelland has had similar interviews with the corresponding associations in Ireland. Other important professional societies, such as the Institute of Chemistry, the Society of Chemical Industry, the Society of Public Analysts, the Society of Dyers and Colourists, the Royal Institute of British Architects, the Faraday Society, and several trade associations, such as the British Electrical and Allied Manufacturers' Association, the Silk Association, the Staffordshire Pottery Manufacturers' Association, the Federation of Master Printers, have been interviewed—in all cases with gratifying results. We have noticed—what, indeed, is well known—that in the main the most highly-organised industries are those which have made most use of scientific research, and are consequently most ready for, though possibly not most in need of, the encouragement it is our duty to afford. The engineering trades, with their attendant group of distinguished professional societies, have long been alive to the need and value of scientific research, while the chemical trades for the most part are so divided and individual in outlook that the various professional societies have had neither the influence nor the means necessary to enable them to take any large share in promoting research in connection with those industries. The textile trades, highly organised as they are on the economic side, had made even less progress in the systematic use of science. They had been content for the most part to leave science to the dyers and the dye-stuff manufacturers, or to the engineers who supplied them with machinery, without much care in either case as to their nationality. The paper manufacturers were in much the same position. But now there are signs of a change, and already textile research into the electrification of fibres during manufacture is proceeding at the University of Leeds with funds provided by the Textile Institute, and proposals are before the Council for fundamental researches into the cellulose fibres which form the basic material of the cotton and paper trades.

(*c*) *Register of Researches.*—While these enquiries and interviews were taking place the Council had invited the assistance of the universities and technical colleges of the country in the formation of a register of researches actually being conducted on the outbreak of the war. Together with the name of the worker and the subject of the research, the register gives the date of its beginning, and, if it has been temporarily suspended, the cause of its abandonment. In collecting these particulars from the technical schools and colleges we have been greatly assisted by the inspectors of the Board of Education. It is not enough, however, to know what original work is going on, who is doing it, or where it is being done. A careful survey is needed of the amount and the character of the provision made in our higher educational institutions for research work. We are accordingly beginning such a survey as part of our preparatory arrangements for a systematic programme of aid to individual researchers. We describe these initial steps below. It is hoped that the register will enable suitable workers to be rapidly found when proposals for special lines of enquiry come before the Council, and that a survey of the directions in which research is now proceeding in our universities and colleges may enable the Council to make helpful suggestions to individual workers from time to time, as the need for research in particular directions becomes apparent.

We also have under consideration the possibility of inducing firms in some at least of our industries to assist the progress of research by informing us in confidence of the problems they have in hand or in contemplation. We appreciate the difficulties involved in an attempt to systematise the interchange, between manufacturers, of knowledge and experience often purchased at great cost, or to proceed more rapidly than the best opinion would approve, or to anticipate those conditions in the home or foreign markets which would make a pooling of knowledge advantageous. But, broadly speaking, we think that any assistance that the industries or even individual firms can give us, from their accumulated experience, in bringing science to bear rapidly upon manufacturing problems will be of benefit to the trade as a whole, and indirectly, if not directly, of advantage to each manufacturer.

(*d*) *Aid to Research in Educational Institutions.*—Among the duties assigned to the Council in the White Paper (paragraph 6) is the formulation of proposals for the establishment and award of Research Studentships and Fellowships. We welcome for this reason the comprehensive and interesting discussion of the whole question of stimulating an adequate supply of trained students, which is contained in the recent interim report of the Consultative Committee of the Board of Education, and we propose to study this report carefully before making any recommendations of our own. But it is evident that no such scheme can be effective at the present moment. Yet, short of a definite scheme, it still seemed possible to make tentative experiments by way of aid to individuals and in the process to gather experience and suggestions for future guidance. The Vice-Chancellors and Principals or Deans of Faculty were accordingly asked to consult the heads of their several departments and to submit proposals, bearing in mind the intentions of the Council as described above, and making it clear that with the heads of the departments and not with the Senates or Faculties or other University authorities would rest the responsibility for the recommendations put forward. It was also explained that in no case would the Council recommend a grant if in the result the funds of the university or college ordinarily available for teaching or research were relieved. The Council have only been able to recommend grants to some 40 individuals, amounting in all to a sum not exceeding £6,000.

We have already made it clear that in our view research in pure science should be as much our care as research in applied science. It is the necessary precedent of all industrial applications, and the universities are peculiarly fitted to pursue it, though it is not possible to do much in this direction during the war. We realise to the full the importance of consultation with the Board of Education and the Scotch Education Department in all matters which may affect the universities, and we are working in close co-operation with these departments. But the nature of our work inevitably brings us into direct contact with the universities and higher technical colleges, and we think that as our relations with these institutions grow closer and more continuous, we may be able to call the attention of both students and teachers to many interesting problems in industrial research, of which we shall become aware in the course of our own work, and that individual members of the Council and their Standing Committees may come to be taken into counsel as to possible lines of research. If this hope is fulfilled, we may help to bring more reality into those academic laboratories which are now much dominated by the text-book and the syllabus of examination, and so encourage a better professional training for chemists, physicists, and other men of science. At the same time we recognise that there is a danger in bringing technical problems too pressingly to the notice of teachers and students in educational institutions. We must not tempt those capable of making advances in natural knowledge to abandon their austere studies for the sake of solving temporary and local technical problems. Still less must students be encouraged to take up such questions except as stimulating incidents in their general training. On the other hand, pure science has in the past owed much to observations, suggestions, and difficulties which have come from activities external to the laboratory or study. So will it be again, and it is our desire so to order the relations of workers in pure science to the industries going on around them that they may receive

the stimulus of a wider outlook than is always attainable under the limitations of an academic system of syllabus and examination. In this way it may be possible in the end to create such an atmosphere that the new generation of students will cease to draw a distinction between "theory" and "practice," and technologists of all ranks will through them attain to the view that sound practice is only theory tempered by compromise.

(*e*) *Formation of Standing Committees.*—We have already remarked upon the relatively high organisation of the engineering profession in relation to the several branches of the engineering industry. One result of this satisfactory condition has been that a number of researches bearing on industrial engineering problems was already in progress before the establishment of the Council. Another result is that a considerable number of applications for aid to new researches was received immediately we got into touch with the professional bodies connected with these great trades. These facts and the representations of the societies urging the establishment of stronger machinery for dealing with the manifold aspects of engineering research convinced the Council at an early date that they must proceed at once in accordance with paragraph 8 of the White Paper to set up a series of strong standing committees to assist them in surveying the field of research, in constructing panels of referees, and in dealing with the applications for grants. The five great engineering societies—the Institutions of Civil, Mechanical, and Electrical Engineers, the Iron and Steel Institute, and the Institution of Naval Architects—submitted a petition to the Privy Council, and were later received by the Lord President in deputation, urging that the Advisory Council should be enlarged by the inclusion of representatives of the several branches of engineering. But steps had already been taken to establish the standing committees referred to, and the Lord President suggested in his reply that the present small Council, with a number of strong representative committees grouped round and supporting it, should be given a fair trial. The societies thereupon submitted their nominations to the Advisory Council, and we desire to express our recognition of the promptitude and zeal with which all the societies concerned have set themselves to make the new Standing Committees a success.

Three Standing Committees have already been set up—a Committee on Metallurgy, under the chairmanship of Sir Gerard Muntz, Bart., with special sections for ferrous metallurgy, under the chairmanship of Sir Robert Hadfield, and for non-ferrous metallurgy with Sir Gerard Muntz as chairman; a Committee on Engineering, under the chairmanship of Sir Maurice Fitzmaurice; and a Committee on Mining, under the chairmanship of Sir William Garforth, with a section on the mining of iron, coal, and hydrocarbons under the same chairmanship, and a section on the mining of minerals other than iron, coal, and hydrocarbons, with Mr. Edgar Taylor as chairman.

Each of the Committees consists of about 15 members, of whom approximately half have been nominated by the professional societies concerned, the remainder being appointed directly by the council. The Committees were appointed in the first instance for the period of one year in order to facilitate any changes in constitution or terms of appointment that experience might suggest. The terms of reference are as follows:—

The Committee will meet from time to time and advise the Council on researches relating to engineering or mining or metallurgy, as the case may be and on such matters as may be referred to the Committee by the Advisory Council.

Members of the Committee will also be invited to act as expert advisers in the formation of special committees of the Advisory Council to consider individual applications for grant in aid of researches. In the formation of such committees the Chairman of the Advisory Council will consult with the Chairman of the Committee or Section concerned, and with those of its members who are specially conversant with the subject of the proposed research.

The Council hope, with the assistance of their Standing Committees, the Professional Societies, the Home Office, and the Board of Trade gradually to construct panels of names which will enable them to obtain the very best advice on the different aspects of the problems they are called upon to solve. The advice they need may be commercial, economic, financial, or scientific. The best opinion in all these spheres will, it is hoped, be available on the panels for the guidance of the Council and their Standing Committees, and will ensure the confidence of the industries concerned that the steps proposed have been considered in all their aspects.

(*f*) *Other Standing Committees in Contemplation.*—The Council realise that the number and scope of the Standing Committees will need extension from time to time, but the absence of strong professional societies working in conjunction with the other scientific industries in this country makes it inadvisable to proceed hastily in so important a matter. In particular the organisation of the Council's machinery for the manifold chemical industries needs cautious handling in the first instance. Up to the present we have dealt with such questions as we have been able to approach by means of small Special Committees of the Council itself, which have been empowered to consult other persons as occasion arose; but at best this must be a temporary expedient. It seems unlikely that a single Chemical Committee, with the large number of special sections that would be necessary, could usefully be established at the present moment, and we are disposed to think that a series of Standing Committees dealing with particular branches of the chemical trades may be the better manner of proceeding. A Standing Committee on Fuel may be necessary; possibly another for rubber, and a third for the chemistry of cotton and paper. A Standing Committee for Textiles, with special sections for cotton, wool, and silk, is also likely to be needed before long.

Parallel Movements in the World of Science and Industry.—The action of the Government in setting up the new machinery for the encouragement of research was accompanied, if not instigated, by vigorous discussion and debate in the public press and the learned societies. The useful work which the Royal Society has done for the Government during the war by means of a series of special committees, and the attempts of societies such as the Chemical Society and the Society of Chemical Industry to arouse an interest in the application of science to industry and the importance of organised effort led the Royal Society to establish a Board of Scientific Societies.

The British Science Guild, which has done much in recent years to impress upon the nation the necessity for scientific organisation, has put forth an emphatic manifesto on the importance of science and the need of educational reform. The Teachers' Guild has appointed an Education Reform Council, including representatives of science, industry, and commerce, while Sir Ray Lankester formed a Committee on the Neglect of Science to deal with science in the public schools, the older universities, and the examinations for the Civil Service. The professors of the Imperial College have presented to the Lord President, as Chairman of their Governors, a memorial dealing comprehensively with the need for a national policy and for a larger output of trained men of science.

But the movement has not been confined to professors and to scientific men. The practical man of business, the manufacturer, and the trader have been as anxious and interested as any. It is not to be wondered at, for they were the first upon whom the significance of a state of war was forced. In the early months of the war the great steel manufacturers were in grave danger from the possible exhaustion of the supply of chemical glass necessary for the testing of their materials and products. The consulting chemists were in the same case, and the Board of Education instituted a census of all the chemical glass available in the educational institutions of the country in view of the possible need for its requisition. The Institute of Chemistry accordingly set up a Glass Research Committee under the late Prof. Meldola, an original member of our Council, and so enabled Prof. Herbert Jackson to indicate the detailed process of manufacturing a number of special glasses, which were rapidly produced by progressive firms. At this point, when the Institute had reached the end of its resources, the Advisory Council were able to assist the production of further glasses.

The pottery manufacturers were hit in another way. The supply of Seger cones, necessary as a guide to the firing of their china and earthenware, was cut off by the war, and they were threatened with closure from this and other causes, but Dr. Mellor, the Principal of the Stoke Pottery School, was able rapidly to supply the need and to manufacture sufficient cones for the whole pottery trade. This incident, however, and Dr. Mellor's researches into the making of porcelain for

chemical ware and pyrometer tubes—an investigation also undertaken, and with considerable success, by Messrs. Doulton, of Lambeth, and the Royal Worcester Porcelain Company—suggested to the Stoke potters the possibility of remedying the dangerous position of their whole industry. The years before the war had seen the gradual exclusion of both earthenware and the cheaper kinds of bone china from the world markets by the hard porcelain for domestic purposes turned out from the continental factories, particularly those in Germany and Austria. Accordingly, the Staffordshire Pottery Manufacturers' Association, with the Staffordshire and Stoke Local Education Authorities, appealed to the Board of Education in June, 1915, to assist them by a special grant for the erection of research laboratories and workshops in connection with the Stoke School. Their desire was to devote the period of the war to experimentation in the manufacture of hard porcelain with British materials, so as to be in the position to compete with the German and Austrian manufacturers on their own ground, and to build up a new and probably more remunerative trade in place of the older trade in earthenware and the cheaper sorts of bone china. The President of the Board received the deputation sympathetically, and promised to refer the matter to the Advisory Council immediately it was constituted. Thus one of the first problems with which we had to grapple was the whole question of the right action to be taken in dealing with a threatened industry, and the probability of success in the substitution of another, though related, industry using different materials and other processes. We gave the matter our most anxious consideration. Visits were made to the works of manufacturers, several important conferences were held in Stoke and in London with the various parties concerned, and the School of Pottery was inspected, the views of Dr. Mellor and other leading experts canvassed, and ultimately the Council decided to recommend a grant for the erection of the necessary buildings and equipment, and an annual grant towards the maintenance expenditure, which is estimated at some £2,000 a year. The necessary land adjoining the Pottery School has been found by the authorities of the school, an annual subscription towards the cost of the investigation has been guaranteed locally, and the Governors of the School of Pottery have placed Dr. Mellor's services at the disposal of a joint Research Committee of the manufacturers and the Governors. The research will be carried out by Dr. Mellor and Mr. Bernard Moore.

Yet another industry which has suffered much from foreign competition is that of silk. Soon after the establishment of the Council the President of the Silk Association, Mr. Frank Warner, called upon the Chairman to enquire whether the Council would be prepared to assist British firms to conduct researches into important problems affecting the industry. Sir William McCormick pointed out that it was difficult to help an industry unless the firms engaged in it would associate actively and co-operate with the Council in any plan that held out a prospect of success. He also suggested that the Silk Association, though formed for the purpose of settling prices, might enlarge its scope to include the prosecution of research, The hint was accepted, a useful conference took place at Manchester with officers of the Council, the Association formed a strong representative Research Committee, including their consulting chemist, a carefully thought-out programme of research was drawn up and the first of a long list of problems is now to be attacked at the Imperial College by Prof. Groom and his staff.

(*To be continued.*)

SHOP INSTRUCTION IN TECHNICAL SCHOOLS.

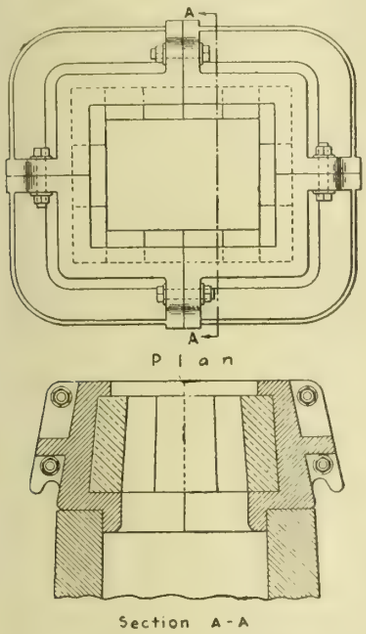
IN the course of a paper entitled "Shop Instruction at the University of Illinois," read before the Society for the Promotion of Engineering Education, B. W. Benedict said that mindful of the undoubted influence of the shop laboratory upon the development of technical education during the past 45 years and acknowledging without reservation the value of shop training, in his opinion conventional shop work or manual training no longer has a place in the curriculum of the technical school which seeks to prepare men for conditions confronting its graduates at the present day. The old formulas which served so well in the pioneer days of industry no longer fit in the new order of things and failure on the part of educators to grasp the significance of the upheaval going on in the industrial world would be disastrous to the shop and correlative subjects. Industry in the past was effective but not efficient. A pioneer product grown to immense bulk on lines of least resistance it knew very little about its complex structure, and was too busy to find out. Large markets not especially particular about price demanded organisation for tonnage production rather than for economical production. Highly specialised service was not required in a large degree, nor was it widely sought.

An inevitable readjustment to changing trade sociological conditions was destined, however, to sweep aside the old structure and supplant it with a new. While the usual processes of evolution had brought about certain changes a new note in industry was sounded in the late eighties, the real effect of which was not apparent for nearly a score of years. Then like a wave "scientific management" swept over the country as the topic of the moment. Not only industry, but society as well, developed an intense interest in this new specific for industrial conditions. Brushing aside all the clap-trap about scientific management which has arisen through misunderstanding of its real significance there stands the unmistakable fact that fundamental changes are taking place in the industrial structure. Principles which ruled heretofore are giving way to those founded upon broader conceptions and higher ideals. Accumulation of knowledge concerning fundamentals is both rapid and wide in scope. The old hazy images around which industry has worshipped are going down before definite standards of attainment, of organisation, of methods. Experience moulded on traditional lines is no longer in such demand as that of the trained specialist, leaving the colleges no alternative but re-organisation of courses of training if men are to be adequately prepared for the service which industry now demands of them. Such a re-organisation presents its difficulties, but it must come and quickly if it is to be effective

The relation between education and industry is indissoluble. The ideals of education are to develop men into better men, morally, mentally, and physically; and if an educational system failed in this mission it would pass into decay as a useless feature of society That it does not decay but continues to exert an ever-widening influence in the development of civilisation is a sign that education has not failed in the practical achievement of its ideals. The conclusion is also obvious that education has continued to meet the ever-changing demands of society. Side by side with the evolution in industry which during the past century has been marked by striking changes from old forms to new, we see equally significant developments in educational methods. From the first, technical education and those special interests of society it aims to serve have enjoyed a particularly close relationship. The first has sought not only to solve technical problems by direct assistance in the research laboratory, but also by offering training to young men for the special services required. Industry in return has taken an active interest in education and exerted a powerful influence on its development. The principal demand of industry on education is that it must be "practical," and courses in shop work seemed in large degree to fulfil this requirement. For 40 odd years the college shop has flourished in an auspicious environment due to the enthusiastic support manifested by those interests which contributed so generously to the advancement of technical education. It has performed a great and useful service and won its right to a place in the higher institution of technical education, but it stands to lose that place if early traditions continue as the source of inspiration for its activities. Originally the one bright "practical" spot in a group of "theoretical" courses, it is now one of the least practical if it offers no more than the traditional form of manual training. Performance of simple shop processes such as have been the rule in these courses without definite relation to elements of time and cost have little value in the training of men who must face modern industrial conditions. Manipulative processes very properly have a place in secondary school training, and some acquaintance with them in that environment is desirable, but the college shop must aim beyond this and administer courses relating to the principles underlying the use of these processes in industry. An understanding of the principles of industrial economics, of shop organisation, of production, and of executive control, is what industry demands of college graduates to-day.

A HOT TOP FOR INGOT MOULDS.

A HOT top for ingot moulds, which employs ordinary-size fire bricks, is in use at the plant of the Donner Steel Company, Buffalo, N.Y. It is the invention of C. E. Duncan, general superintendent of the company, and application has been made for a patent. Its simple construction is indicated in the accompanying drawings, for which we are indebted to "The Iron Age." Four corner castings are bolted together forming the cap, which rests on the top of the ingot mould. The cap is lined with the bricks, and an important feature is that no special shapes are required but regular commercial bricks



DUNCAN HOT-TOP FOR INGOT MOULDS.

suffice. The refractory and non-heat conducting property of the brickwork serves, of course, to keep hot as long as possible the upper part of the freshly cast ingot, thus serving as a sink head and as a means for minimising piping in the ingots. The experience at the Donner plant shows that it is efficacious in this regard. The head is readily removed, lugs projecting from the casting to allow of the use of crane hooks, and it may be used over and over again until it becomes necessary to reline the top with fresh bricks.

THE METALLURGY OF ZINC.*

BY ERNEST A. SMITH, A.R.S.M., M.INST.M.M.

IN extracting zinc from its ores advantage is taken of the volatility of the metal at a bright red heat, practically all the zinc of commerce being produced by the method of distillation. The material almost exclusively employed in its production is zinc oxide, obtained by calcining the carbonate (calamine) or by roasting the sulphide (blende or sphalerite), only a comparatively small quantity being obtained from the silicates (willemite and hemimorphite).

The distillation process is dependent on the reduction of zinc oxide by carbon, or carbon monoxide, and to effect this the powdered oxide is mixed with coal, and exposed to a very high temperature in fireclay retorts. The carbonaceous matter must be in excess to prevent the formation of carbon dioxide, which acts as an oxidising agent on the gaseous zinc.

The metallic zinc liberated, distils off, and is condensed in clay receivers adapted to the retorts, and a continuous stream of carbon monoxide issues from the retorts. Zinc silicates are also reduced by carbon, but require a higher temperature than the oxide. As pointed out by Gowland: "The condensation of the gaseous zinc to fluid zinc is a matter of some difficulty, as it can only be effected within a limited range of temperature, viz., 415° to 550° C. Below 415° C. it condenses to a powder called zinc fume (or blue powder, in America)—*i.e.*, metallic zinc in the form of powder mixed more or less with 8 to 10 per cent. of zinc oxide. If much above 550° C. it is not condensed at all. There is likewise another difficulty. If the zinc vapour is much diluted with other gases it will not condense to fluid zinc, but as zinc fume."

In preparing the ores for distillation, carbonate ores are converted to oxide by calcination in simple shaft furnaces or in reverberatory furnaces. According to Moulden, the calcination is seldom complete, and as much even as 15 per cent. CO_2 may be left if the ores are very calcareous or magnesian.

For roasting crushed zinc blende a large variety of furnaces is used, including (1) hand-raked reverberatory furnaces, with one or two hearths, or with shelf burners; (2) mechanically raked furnaces, such as the Zellweger and Merton furnaces; and (3) muffle furnaces in use for burning blende for sulphuric acid manufacture, of which the Hegeler furnace is a modern type. Although hand-raked reverberatory furnaces with two super-imposed hearths are still in use in Europe for roasting blende, they are gradually being replaced by the more economic and efficient mechanical and muffle furnaces.

The Merton furnace is said to be in successful use at two of the chief spelter works in Swansea. This is a reverberatory furnace, with three superposed hearths, and a special finishing hearth, with revolving rabbles worked by machinery.

The Hasenclever furnace is, according to Ingalls, the most generally used muffle furnace in Europe for roasting blende, for utilising the gases for sulphuric acid making.

Another furnace which appears to be gaining favour in Europe is the De Spirlet. This is a multiple-hearth turret furnace in which the hearths themselves are revolved, projecting teeth from the bottom of one hearth rabbling the ore on the hearth next below. The furnace is ingeniously designed so that it may be dismantled quickly for repairs, and it desulphurises blende with very low fuel consumption, given as 10 per cent. or less. This furnace has been installed recently at the works of the Grasselli Chemical Company in the United States.

The furnaces most favoured in America for roasting blende appear to be the Hegeler and the Zellweger, the former being employed invariably when the roast gas is to be used for sulphuric acid manufacture. The improvements in the Hegeler furnace since its introduction about 30 years ago have been only in structural features and mechanical details. Most of the new zinc-smelting plants of the United States, built in the eastern coal-fields, are designed to make sulphuric acid, and are equipped with mammoth Hegeler furnaces capable of roasting about 50 tons of ore per day.

The Zellweger furnace is a long hearth reverberatory furnace of the Brown "straight-line type," from which it differs in the form of the rabble and the supporting mechanism. Although its consumption of fuel is comparatively large it is now well established for blende roasting in Kansas and Oklahoma, where the roast gases are not utilised. The old type of Brown furnace, known as the "horse-shoe furnace," is also still in extensive use in the United States for roasting zinc blende, but according to Ingalls the later Brown "straight-line" furnace is much superior for the purpose.

For the extraction of the zinc from the calcined or roasted ore, three types of retort furnaces, viz., Belgian, Silesian, and Rhenish (Belgo-Silesian), are in use, which differ mainly in the form of retort used. The Belgian type of retort is the smallest, and the Silesian the largest. The Belgian and Silesian furnaces formerly in extensive use are gradually being replaced on the Continent and in England by the Rhenish type of furnace. The Belgian furnace is, however, still in very extensive use in the United States, although here also in the more recently erected plants the furnaces have been so modified that they may be classified as Rhenish.

Hand-made retorts still continue to be used in many works in England and on the Continent, but practically all the smelters in the United States are rapidly taking up the hydraulic retort-making machine for the manufacture of their retorts. The machine in use in America has two plungers, which act upon a compact ball of well-prepared clay, pressing it into a finished retort at about 1,500lbs. pressure. Such retorts are greatly superior to those made by hand, as they are denser, and on that account are more durable and less permeable by zinc vapour. They are also less readily attacked by any basic material contained in the ore. The American

* From a paper on "The Development of the Spelter Industry," read before the Institute of Metals, September 29th, 1916.

clays are inferior in quality to the European, but efforts are being made to rectify this difference artificially. The superior clay of the European retorts permits of the "hard driving" or distillation at a very high temperature, as practised in Germany and Belgium, but which is unknown in America. Distillation under these conditions means higher extraction of zinc, and American smelters are directing attention to the making of retorts to equal in quality those made in Germany.

With regard to the furnaces employed these are of simple construction, consisting of a narrow vertical arched chamber, in which the retorts are arranged in parallel rows, one above another, supported only at both ends in order that they may be surrounded by flame. The older furnaces have a fireplace at the bottom of the chamber, but all modern furnaces are gas-fired. This is the result of the increasing amount of roasted blende received by the smelter, which requires a higher temperature for reduction than calcined calamine. The adoption of gas-firing is now becoming very general, the gas being supplied from gas producers built either in or near the furnaces, or entirely independent of them. In America natural gas was formerly extensively used for heating zinc distillation furnaces.

Producers of the Boetius type are used in the older furnaces in Belgium, but as the tendency in building new furnaces is to adopt the Rhenish form, the Siemens regenerative system is becoming very general in modern practice. Other producers, however, are employed in some works. Gas-fired Rhenish furnaces, without regenerators, are in use in the Rhine provinces. At one of the typical spelter works in Swansea, South Wales, furnaces of the Rhenish type, with gas as fuel and regenerative chambers for gas and air, are employed. The gas is generated in producers of the Siemens type.

The metallurgy of zinc involves only two operations, viz., roasting and distillation, to yield marketable metal, and is therefore simple, as compared with the metallurgy of metals such as copper involving some five operations, but the conditions of the reduction of zinc oxide to metal are, as pointed out by Sulman, difficult and peculiar, and the reactions involved highly endothermic.

The ore charges, which are necessarily kept in the condition of coarse powder throughout the operation, are very poor conductors of heat, while to extract the metal it is necessary to continually supply heat energy by external heating of the retorts. "This imposes a maximum charge thickness of about 8in., a 24 hours' reduction period (from charging to recharging), the provision of small-sized retorts of specialised construction, and with only about six weeks' life, and general the handling of large bulks of raw material in very small quantities. Also it does not pay to carry the extraction of the spelter below a certain limit, the 'seconds' or residues are dumped still carrying several units of zinc." Nevertheless, viewing the present status of the practice in zinc smelting, one is impressed by the high extraction results, the low fuel consumption made possible by regenerative gas firing, and the reduction of labour involved in the art.

While progress has been made in the metallurgy of zinc of late years, it has not been characterised by any great change in method or in the discovery of new principles, but rather by a continuous and steady increase in the productive capacity of the existing works, and by the installation of new plants. Nevertheless, the minor changes have been important, and have been directed mainly towards higher extraction results and the reduction of labour. While several new processes are being experimented with on a comparatively small scale, these are not yet sufficiently developed to judge what influence they will have on the future methods of metallurgical treatment. As recently pointed out by Prof. Bacon, "The great problems at present in the metallurgy of zinc are in concentration of the ore, and in the treatment of flotation concentrates." The latter produces the troubles always experienced with fine ore; it is difficult to roast, and the distillation of it is also not simple.

Chief among the changes in zinc smelting in recent years are those in the method of firing, and the adoption of the Rhenish or intermediate type of retort, and of machine-made retorts. By the use of regenerative gas firing and well-adapted condensers, the cost of production has been reduced and loss of metal prevented. In direct-fired furnaces the coal consumption is about 2 tons or more per ton of ore smelted, while in modern gas-fired Belgian furnaces the consumption of coal for fuel is about 1·6 ton per ton of ore smelted. For Rhenish gas-fired furnaces the average is about 1·1 to 1·2 ton, but much necessarily depends on the quality of the coal supplied to the producer. With a view to the reduction of the cost of labour, mechanical appliances for charging and cleaning the retorts have been introduced in several European works, and more recently in American works, but they have not met with general favour.

The ore charged into the retorts generally contains about 45 to 50 per cent. of zinc. The weight of the charge varies with the size of the retorts, the Belgian retorts in the United States taking about 60lbs., plus a small quantity of by-products, exclusive of reduction material, while for Rhenish retorts in Europe it is from 75lbs. to 90lbs. Although the Saeger charging machine is now in regular use at the works of the National Zinc Company, at Bartlesville, Oklahoma, where it was introduced in 1913, the common arrangement of the distillation furnaces in American works is unfavourable to the use of a charging machine, American practice being to set the furnaces in parallel, whereas in the European practice they are commonly set in series, *i.e.*, in a single row, thus allowing more room for manipulation. Machine charging takes 1 hour, as compared with 3 hours for hand charging, and the ore is charged more densely, enabling 2,000lbs. more ore to be charged into the furnace. Two difficulties, however, attend machine charging when applied to the excessively fine flotation concentrate now coming to the zinc smelters. This very fine ore sticks to the augers, necessitating frequent cleaning during charging, and also tends to "blow out" with considerable force, sometimes only 20 minutes after the retorts have been charged.

The method of removing the residue from the retorts, generally employed in Europe, is to rake it into a pit in front of the furnace, while in America the common practice appears to be to use a long iron pipe, with water flowing from the end, which is pushed to the back of the retort, where the water is converted into steam by the heat, throwing the charge forward. By this latter method a considerable amount of fine material is blown away, causing loss of any silver or lead contained in the residue. A retort-discharging machine has recently been patented by J. J. Simmonds, of Iola, Kansas, which in the opinion of some distinguished American zinc metallurgists has solved the problem of mechanically discharging retort residues. Arrangements are now being made to install the machine at three works in America. The machine consists essentially of a truck carrying a series of bars, or plungers, with sprockets at each end of the bar, over which travels an endless chain of scrapers. The machine is run up facing a tier of retorts, into which the scrapers are introduced and set in motion; the mechanical arrangements being very ingenious. The scraper chains are sprayed with water to keep them cool.

The composition of the residues naturally depends on the composition of the ores treated, but with ordinary ores the residue contains, as a rule, from 4 to 8 per cent. of zinc. With leady ores practically all the lead and silver will be found in the residues. After concentration by grinding, screening, and jigging, they are sold to lead smelters, who also value them for their iron contents, which acts as a flux. German smelters prefer zinc ores containing sufficient lead and silver to yield a residue which can be sold to lead smelters. The amount of lead admissable in the distillation process is usually considered to be limited to about 10 per cent. Moulden has stated, however, that he has successfully roasted and distilled some thousands of tons of zinc ore, containing from 14 to even 20 per cent. lead. With due exercise of care and the selection of appropriate retort materials, the difficulties due to the presence of lead may be overcome to such a degree as to allow of entirely profitable commercial working. As Mr. Moulden points out, this is of far-reaching importance, as vast additional potential sources for the augmentation of spelter supply have thereby been rendered available, with the prospect of further ones now well within sight.

Careful attention is also being given in America to the gangue constituents of the ore, and the composition of the ash from the reducing agent employed with a view to reducing the amount of slagging in the retorts. Iron, lime, and manganese are objectionable impurities, although the presence of some iron is desirable. Few American smelters care to have more

than 2½ per cent. of iron, but in Europe as much as 7 to 8 per cent. is allowed. The utilisation of the unburnt coal in retort residues is another matter claiming the attention of American zinc smelters. The residue, which contains a good deal of unburnt coal, is screened, and all over ¼in. size, mixed with about 20 per cent. of fresh coal, and used as fuel under boilers. So far this mixture has proved serviceable at the Edgar Zinc Company, and 10 boilers are now fired in this way.

In modern German and Belgian practice a 90 per cent. yield of spelter is constantly reached with roasted blende carrying 50 per cent. zinc. In the Western States of America the yield from a 40 per cent. ore is stated to be about 75 to 80 per cent., but in the newest plants efforts are being made to bring the yield up to that in continental works. The English zinc smelters cannot claim equality with the better continental or American practice, the yield in this country being usually nearer 85 per cent. A certain amount of conservatism and perhaps an undue regard for local tradition are partially responsible for this lower recovery. Although progress has been made, and gas-fired furnaces have almost completely replaced the older Welsh-Belgian type, a good deal remains to be done to bring English practice up to the level attained to in several continental centres.

For example, the hydraulic pressed retort, so invariably used abroad, has yet gained but little popularity in this country, where the heavier hand-made and more expensive article appears to be still the rule. Little attention also appears to have been given to the "briquetting" of fine ore, as opposed to the ordinary "loose charging" methods. This method, which was proposed by Sulman and Picard for dealing with Broken Hill zinc-lead concentrate, consists in briquetting the material with bituminous coal and pitch, and distilling the briquettes in an ordinary distillation furnace, when the carbonaceous residue, which acts as a filter, is found to contain most of the lead in the metallic state, and is suitable for lead smelting. Very little lead is said to go over with the spelter. Notwithstanding the increased working charge of from 1s. 6d. to 2s. per ton of material briquetted, and the installation cost of the necessary plant, it is claimed the advantages are pronounced. A furnace will take from 50 to 75 per cent. more ore than when loose charged, all other distillation costs remaining the same, whilst charging and discharging operations are more rapid and cleanly.

English smelters are dependent on imported ores, the total importation of zinc ores in 1913 amounting to 65,000 long tons. Of this amount approximately 18,000 tons came from Australia, 14,000 tons from Italy, 9,000 tons from Algeria, 6,000 tons from Spain, and the remainder from other sources, including 1,000 tons from Canada. American smelters treated some 855,000 short tons of ore in 1914, of which about two-thirds was blende and one-third calamine. The bulk of the calamine ore was smelted by works in the gas-fields of Kansas and Oklahoma. The smelters east of the Mississippi river make sulphuric acid, with the exception of two small concerns, and naturally use blende.

With the movement of the zinc-smelting industry to the eastward, the separation of blende roasting and zinc distillation is becoming more pronounced, as it has been for a long time in Europe. It is often good practice to roast the blende at some good centre for the distribution of the sulphuric acid, and then reship the roasted ore to a suitable point for zinc distillation. This is now being done by several large concerns. "The loss of zinc in smelting 25 per cent. ore by the Silesian method varies between 25 and 35 per cent., that in smelting 45 to 50 per cent. ore by the Belgian and Rhenish processes being between 10 and 15 per cent. in the best-operated plants; the loss in retorts by either process is about 3 per cent. per day. The combined cost of roasting and distilling one ton of ore has been estimated by Ingalls at £1. 13s. 2½d. to £2. 0s. 3d. for various plants in the United States and Germany."

In no department of metallurgy has development been more rapid in recent years than in the treatment of so-called complex ores, in which zinc blende is associated with galena and other metallic sulphides. Mechanical dressing and magnetic and flotation processes of concentration have done much towards solving the problem of complex ore treatment, as by their aid a separation can be made which will give products suitable both to the zinc and lead smelter, and also in some cases an iron sulphide product suitable for the manufacture of sulphuric acid. Following the pioneer work of Wetherill's high intensity magnetic separator, much progress has been made in magnetic separation, and many machines introduced.

Electrostatic methods for the separation, by electric repulsion, of good conductors (such as certain metallic sulphides, magnetite, and hæmatite, &c.) from poor conductors (such as silicates, carbonates, oxides, and sulphates, and including zinc blende) were first applied in practice by Blake and Mechernich, and followed by Sutton and Steele and Huff, and others. Huff discarded the electrostatic generator of the Wimshurst type, and employs a dynamo-current of suitable intensity.

The separator is thus capable of adjustment to any required strength of electrical field, and is less liable to interference from climatic conditions. In other particulars it broadly follows previous designs. Magnetic separation of blende and pyrite may be accomplished without preliminary roasting by the use of high intensity magnetic separators of the Wetherill type, the zinc mineral being lifted out of the mass. The more usual practice, however, is to give the mineral a magnetic or "flash" roast, rendering the iron magnetic, after which it is separated from the mass by separators of the low-intensity type, such as the Dings. The limiting factor of electric separators appears to be their inability to handle fine powders, and their liability to dust trouble, unless the dust be first removed.

Flotation processes of concentration have rapidly come to the front since their introduction some ten years ago. It is to the Elmore Brothers that the honour belongs of first bringing oil-mineral processes into the region of commercial applicability and of securing the first success therein; their work focussed the attention of metallurgists upon the great possibilities of these methods. In addition to concentrate suitable for smelting, the flotation processes produce a certain amount of slime, the metallurgical treatment of which is the great problem of zinc smelters at the present time. This material is exceedingly fine, varying from 80 to less than 200 mesh, and produces the trouble that fine ore always does metallurgically, and in addition thereto some that are peculiar to the metallurgy of zinc. The loss of zinc in roasting is particularly large, and appears to be due not merely to dusting, but also to reduction and volatilisation. (Ingalls.)

In view of the fact that the supply of flotation and other concentrate and slime is bound to increase, metallurgists are making every effort to find a solution to its commercial treatment. Several methods have been proposed for treating roasted zinc-lead concentrate (Broken Hill slime) in ordinary zinc distillation furnaces for the production of a pure spelter, and a residue suitable for lead smelters. While lead is sensibly volatile in zinc vapour it may be separated therefrom to a considerable extent by the filtration of the metallic vapour through a porous medium. This fact was utilised, about 12 years ago, by Rev. E. W. Hopkins, who used a filter of charcoal or coke, but other porous materials have since been used.

A zinc fume filter in use at Irvine, on the Firth of Clyde, consists of a fireclay tube filled with loosely packed refractory material, such as chippings of burnt fireclay, which is fitted into the back of the condenser, so that the zinc vapour passes through it. The lead is retained in the material of the filter, while the zinc is condensed in the condensers and contains less than 0·6 per cent. of lead.

In the "briquetting" process, the filtration takes place in the pores of the briquette itself, and the lead is found in the carbonaceous residue in the metallic state, and is suitable for lead smelting. Other methods proposed for the treatment of zinc-lead concentrate and zinc-bearing complex ores may be conveniently grouped under three heads, viz.: (1) smelting processes; (2) electric smelting processes; (3) hydrometallurgical processes.

The smelting of complex ores suffers from two main disadvantages: upon the one hand they contain too much lead for the ordinary distillation process, and on the other they contain too much zinc for lead smelting, their reduction in the blastfurnace being hindered by the excess of zinc, which requires special amounts of flux, and thus is slagged off and lost unless the slag is specially treated to recover the zinc. In this connection reference must be made to Dr. H. Papes' method in use at the lower Harz Mines of Oker for the treat-

synchronise with, the natural periods of vibration either in part or the various complex ores from the Rammelsberg deposits, the main varieties of which are lead ores with 9 per cent. lead and 20 per cent. zinc, and copper ores with from 1 to 15 per cent. copper and 1 to 20 per cent. zinc. They are treated in the ordinary way in blastfurnaces, after first subjecting the lead ore to a sulphurising roast and removing some of the zinc by leaching.

The slags, containing from 22 to 27 per cent. of zinc oxide, are crushed to 50 mesh, and briquetted with coke dust and a binding agent. The briquettes are reduced in a continuous reverberatory furnace, where the zinc after volatilisation as metal is carried off as oxide by the flue gases and is collected in chambers and bag-house plant, the better quality being sold for paint, the poorer to the zinc smelter for reduction to spelter. According to Sulman, "Nearly 10,000 tons of metal are reported to have been thus produced, and 42,000 tons of zinc slags, besides low-grade ores, treated by this method in 1910." Sulman remarks that "zinc residues from spelter production should be amenable to similar processes, large scale trials having demonstrated the possibility of their profitable handling by such methods, when modified in certain details to suit the material."

"Under conditions of forced oxidation, such as in the blastfurnace or blowing hearth, lead is as freely volatilised in the form of oxide as is zinc, a fact which has been utilised in Germany, where the blowing of oxidised low-grade zinc-lead ores has been practised, bag-house plant being employed to collect the mixed oxide fume; this is then treated with sulphuric acid for the production of crystallised zinc sulphate, the residual lead sulphate being sold to the smelter."

The extensive manufacture of zinc white in New Jersey and Pennsylvania is a striking example of the successful treatment of a complex ore. Franklinite ore is obtained in New Jersey and consists mainly of franklinite, willemite, zincite, and various silicates containing manganese. The dressing of the ore produces (1) a concentrate composed mainly of franklinite; (2) a concentrate consisting of franklinite, with various manganiferous silicates; and (3) a mixture of willemite and zincite. The two former are employed for the production of zinc oxide, and the last for direct spelter manufacture.

The oxide is produced by the Wetherill process, which consists in roasting the ore, then mixing with anthracite powder, and spreading it over a layer of burning anthracite on the grate of a kiln, through which a low blast from a fan is forced. The zinc distils off, and is oxidised at once by the carbon dioxide formed during the reduction of the zinc oxide, and by the air present. The gaseous products carrying the zinc oxide are passed through a cooling tower to a series of woollen bags, in a bag house, where they are filtered and the oxide collected. The bulk of the zinc oxide of commerce is produced by this process.

The Wetherill process, somewhat modified, has been in use at Coffeyville, Kansas, for the treatment of mixed zinc and lead ores containing not less than 30 per cent. of lead and zinc combined. The ores are mixed in such proportions that the pigment shall consist of about two thirds zinc oxide and one-third lead sulphate and oxide. They are first roasted in M'Dougall furnaces, and then treated as described above, except that the fume passes first through a combustion chamber to burn off any carbonaceous matter and then passes to a sheet iron flue about 700ft. long, which terminates in a small settling chamber, placed just before the bag-house. Here the cooled fume enters a suction fan, and is forced into the bags in the bag-house, the pigment being collected in the usual manner. Instead of furnaces of the type used in the Wetherill process, Blum has recently proposed pots such as are used in the usual lime roasts in the Huntington-Heberlein process for lead ores. A small plant for the manufacture of zinc white from ores is now being erected in Mexico for carrying out his proposal.

(To be continued.)

The New President of the British Association.—At the recent annual meeting of the British Association, held at Newcastle-on-Tyne, the Council unanimously nominated the Hon. Sir Charles A. Parsons to fill the office of president of the Association at the Bournemouth meeting next year.

THE DESIGN AND GRINDING OF METAL-CUTTING TOOLS.*

BY J. WENDALL COLE.

MAN has been described as "The Tool-using Animal": The invention of the Whitworth screw-feed lathe was a great stride in bringing a rapid duplication of standard work over the hand turning of previous practice. Another leading step for standard duplication of product is the machine grinding of the cutting tools to have their angles and shapes standards and duplicates. First design the steel-cutting tool with proper proportions and angles for strength, for clearance, and for cutting the metal, whether for cast iron or steel.

On tool design and angles, William Kent, in the seventh edition of his "Machinery Engineering Pocket-book," quotes "Hütte," the German engineer's pocket-book, giving the following cutting angles for using least power:—

	Rake. Top	Cutting Edge. Angle of
Wrought iron	3°	51°
Cast iron	4°	51°
Bronze	4°	66°

The best angles must, however, be guided by experience.

Mr. J. Sellers Bancroft says in Vol. 28 of the "Transactions of the American Society of Mechanical Engineers": "In 1869 I made a number of experiments at the works of William Sellers & Co., where I was then shop foreman, and demonstrated that the round-nosed tool would take a cut having a feed from 25 to 33 per cent. coarser than the diamond-point tool would take in the same material and same depth of cut, with the added advantage that on cast iron, the final chip being so much thinner, the material was left in much better shape for the finishing tool. The advantages of this form of tool and the importance of having uniform angles of clearance and top rake, showed the importance of having these tools ground by machine, and in 1874, former slide rests, arranged to attach to regular grindstone boxes, were put into service and used regularly for this purpose. The advantages of this system were so apparent that in 1864 a more fully organised machine was constructed, using a special form of emery wheel on which all tools used on the machines, whether for lathe or planer, external or internal work, or screw-cutting, could be finished to definite angles and sizes, and thereafter all tools used in the shops of William Sellers & Co. were so ground. In 1883 a long series of experiments were tried on a 48in. lathe to determine the power required for various depths and widths of cut, on both steel and cast iron, and the information thus gained was used thereafter in the designing of machine tools.

The late Fred W. Taylor, past-president of the American Society of Mechanical Engineers, says in his paper, "On the Art of Cutting Tools," Vol. 28 of the "Transactions": "Why cutting edge of tool should be curved: Principal object in having the cutting edge of tool curved is to ensure against damage to the finished work"; and again, in the same paper: "Tools with broad noses having for their cutting edges curves of large radius best to use except for risk of chatter."

Upon this question of chatter, Dr. Nicolson, in describing his experiments, published in "Transactions," Vol. 25, says: "The wave length of the force curve is about 0·6in. for this experiment, and it varies between 13,000lbs. and 8,000lbs. It will be observed that the force attains a maximum soon after the cutting commences to crack or shear across, and that it drops to a minimum when the small piece of cutting falls off the forging. At such a slow speed as this (one foot in five hours) the cutting has time to shear off right across in separate fragments, whereas it forms a continuous curl of considerable rigidity when the cutting speed is higher than a few feet per minute."

From these experiments and his own experience, Mr. Taylor concludes in Vol. 28: "Since the thickness of the shaving is uniform with straight edge tools, it is evident that the period of high pressure will arrive at all points along the cutting edge of this tool at the same instant and will be followed an instant later by a corresponding period of low pressure; and that when these periods of maximum and minimum pressure approximately correspond to, or

* Abstract of paper read before the American Association for the Advancement of Science.

the forging, the tool, the tool support, or in any part of the driving mechanism of the machine, there will be a resultant chatter in the work. On the other hand, in the case of tools with curved cutting edges, the thickness of the shaving varies at all points along the cutting edge. From this fact, coupled with Dr. Nicolson's experiments, it is obvious that when the highest pressure corresponding to one thickness of shaving at a given point along a curved cutting edge is reached, the lowest pressure which corresponds to another thickness of shaving at another part of the cutting edge is likely to occur at about the same time, and that therefore variations up and down in pressure at different parts of the curve will balance or compensate one for the other.

"It is evident, moreover, that at no one period of time can the wave of high pressure or low pressure extend along the whole length of the curved cutting edge. For this reason a curved cutting edge tends to prevent chatter."

Continuing, he says: "Reasons for adopting the particular curves chosen for the cutting edges of our standard tools: It will be noted that as the body of the tool becomes smaller, the radii of curvature of the cutting edge also become correspondingly smaller. This change in the curve of the cutting edge is rendered necessary by the fact that the smaller tools are used in the small lathes, which, generally speaking, work upon small forgings from which cuts are removed which are both shallow in depth and have comparatively fine feeds. Forgings which are small in diameter are quite as liable to chatter as the larger forgings which are machined in larger lathes, and in order to avoid this chatter it is necessary that a curve for the cutting edge should be chosen which will give a variation relatively in thickness of shaving even in small depths of cuts. Thus, for the avoidance of chatter, the curve of the cutting edge should be small in proportion as the depth of cut and feed which it normally takes are small."

As will be seen later, the small radius of curvature of the cutting edge involves a diminution in cutting speed. Therefore, with larger sized tools it becomes important, on the other hand, to take as large a radius of curvature for the cutting edge as is compatible with freedom from chatter. The coarser feed which usually accompanies the larger tool also calls for a larger radius of curvature at the nose of the tool, in order that the ridges left by the spiral path of the tool along the forging shall be as low as practicable.

The all-round adaptability of the standard tool to a variety of uses also calls for a smaller radius of curvature the smaller the tool, since standard roughing tools are continually required to run up against a shoulder or into a corner of the work, and the fillet in this corner is normally small in proportion as the forging or casting is small. Tools which are to be used for cutting cast iron and hard steel have slightly larger radii of curvature than those which are to be used for the softer steel and wrought iron. The reason for this change is that much slower cutting speeds must be used in cutting hard steels than for soft, and this is also to a less degree true for cast iron as compared with soft steel.

Cast iron is cut with less cutting pressure or resistance to the tool than is required for soft steel. Therefore, in a given lathe a greater depth of cut and coarser feed can be taken on cast iron than on soft steel: and, as explained before, the coarser the feed the greater should be the radius of curvature of the extreme nose of the tool in order to leave an equally smooth finish. Where local shop practice calls for a comparatively shallow cut and broad feeds, such shops should have standard tools especially designed for such work.

Clearance Angle of the Tool.—The following are our conclusions regarding the clearance angle of the tool:—

(*a*) For standard shop tools to be ground by a trained grinder, or on an automatic grinding machine, a clearance angle of 6° should be used for all classes of roughing work. (*b*) In shops in which each machinist grinds his own tools a clearance angle of from 9° to 12° should be used, because hand grinding varies so much.

The larger the clearance angle, the greater will be the ease with which the tool can be fed (wedged or driven) into its work. On the other hand, every increase in the clearance angle takes off an equal amount from the lip angle, and therefore subjects the tool to a greater tendency to crumble; the clearance angle must be sufficiently large to avoid rubbing the flank of the tool against the spiral flank of the metal being cut.

Lip Angle of the Tool.—In brief, Mr. Taylor's conclusions may be stated: For standard tools for cast iron and the harder steels grind with a clearance angle of 6°, back slope 8°, side slope 14°, giving a lip angle of 68°.

For cutting steels softer than, say, carbon 0·45 per cent having about 100,000lbs. tensile strength and 18 per cent stretch, tools should be ground with a clearance angle of 6°, back slope of 8°, side slope of 22°, giving a lip angle of 61°.

The most important consideration in choosing the lip angle is to make it sufficiently blunt to avoid the danger of crumbling or spoiling at the cutting edge.

When such tools have been designed for the work in hand, for the best results in grinding, the steel tool should be held in a chuck and presented to a V shaped wheel with 90° included angle, for convenience in grinding the different faces of tools, for increasing the available grinding surface, and to enable small and delicate splining tools to be ground." Also, that a tangential line contact of wheel and surface ground can always be maintained, thus permitting a constant flood of water upon the line of contact, and allowing much more rapid grinding than where wheel and tool have a surface contact. "The tool-chuck can be rotated about a horizontal axis parallel with the shanks of the tool, and can readily be set up to any angle by means of a graduated circle and vernier reading to $\frac{1}{10}$°. It is carried in a frame which can be rotated about a vertical axis passing near the point of the tool, and can be set to $\frac{1}{10}$°." Thus it becomes a universal tool grinder for all shapes and sizes except concave.

Engineers have in recent years advised and perfected standard work in all lines of manufacture, and capitalists are rapidly adopting these standards in leading lines. But many financial managers, and also some engineers, are not aware of the fact that while adopting standard construction, cranes, machine tools, steels, and foundry metal to make a standard product they are overlooking a very important link in the chain of production when they omit standard shapes of cutting tools. One weak link measures the power of the chain.

The whole object of an engineering works from purchase of real estate to sale of product is to change rough metal into finished product the most rapidly and with the least expense. The keynote of the whole production is the angle of the cutting tool. More chips, size of pay roll, and dividends all depend upon it.

To get the benefit of high speed steel tools they *must* be ground at proper angles, for if used upon old machine tools, the wrong angles of a majority of hand ground tools soon wreck the machine tools. If used upon modern machine tools designed for using high speed steels, the difference in strain between using proper angles in the cutting edge and wrong guesswork angles may run into tons, cause tools to dull sooner, a loss of time in changing tools, and a waste of not only high speed steel but at present very high priced steel in dulling and needing grinding so soon again.

HARDENING AND TEMPERING OF EUTECTOID STEEL.

At a recent meeting of the American Society for Testing Materials, Dr. Henry M. Howe and Arthur G. Levy presented a paper entitled "Notes on the Hardening and Tempering of Eutectoid Carbon Steel and on the Shore Test," of which the following is a summary:—

If eutectoid steel is heated to 800° C., and quenched either immediately or after slow cooling to one or another of a descending series of temperatures, the volume of the quenched steel decreases progressively as the quenching temperature sinks towards the recalescence or Ar1, showing that the arrest of the transformation by the quenching becomes progressively less complete, whereas little change in the resultant hardness occurs. As the quenching temperature is lowered from above to below Ar1 the decrease of volume is greatly and suddenly exaggerated, and a sudden loss of hardness occurs. Further lowering of the quenching temperature does not affect the volume, showing that the transformation completes itself on passing Ar1. The hardness decreases progressively because of

the increased opportunity for the coalescence of the cementite and ferrite respectively.

The microstructural changes caused by tempering are obscure, and seem to be even less usefully indicative than the fracture. The oxide colours found in the tempering cracks are the deeper the longer the tempering at given temperature.

The observed Shore hardness increases with the thickness of the specimen, and with the distance from the edge of the specimen, within limits. The hardness also increases on superposing well-fitting specimens, but not when many specimens are set on one another, probably because of the cumulative effect of surface inaccuracies. It is not known what thickness and distance from the edge are required for true readings, but neither a thickness of 0·62in. in hardened eutectoid steel nor a distance of 0·078in. from the edge in tempered steel of about 0·20 per cent. of carbon suffices.

On repeating the Shore test in the very same spot, the observed hardness at first increases rapidly, and thus becomes about tripled, so that that of dead soft ferrite equals that of hardened eutectoid steel. After numerous repetitions the observed hardness drops abruptly, often apparently to zero, to recover to or above the previous maximum. This recovery may be spread out over as many as 12 successive impacts.

Increasing frequency of test, though its effect is obscured by these abrupt drops, seems to accelerate the increase of hardness slightly.

The Shore hardness of such a conglomerate as unhardened eutectoid steel may on one hand be extremely uniform, or on the other hand it may vary greatly, with a surprising tendency to be concentrated on two numbers about midway of the range, and to avoid the numbers intermediate between these two.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

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Steam generators. Winslow. 12168.
Coating of metal plates with tin, terne, or other metal or alloy. Taylor. 12311.
Process for de sulphurising, reducing, and refining nickel ores. Burrows. 12358.
Automatic positive clutches for power presses. Flower & Firth. 12390.
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Lathes. Cole. 13284.
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Internal combustion engines. Lake. 17294.
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Manufacture of metal ingots. Steel, Peech, & Tozer, and E. H. Saniter. 497.
Valves for internal-combustion engines. A. W. Reeves. 2566.
Friction clutches. L. Dufour. 3667.
Construction of vices or clamps. H. Southon. 4050.
Internal combustion engines. D. Ruva. 4618.
High speed oil engines. P. Dempsey. 5297.
Steam traps. Steam Fittings Company, and B. Wiesengrund. 5452.
Valve mechanism of internal-combustion engines. L. F. Godeau and P. Bright. 6755.
Lifting jacks. W. J. Mellersh Jackson. 7171.
Internal combustion engines. O. Imray. 7717.
Steering and propelling apparatus for surface and submarine vessels. H. Middleton. 10357.

ELECTRICAL, 1915.

Electrical systems for use with internal combustion engines. Kettering & Chryst. 7757.
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Systems of electric ship propulsion. British Thomson-Houston Company. 12444.
Method of generating high-frequency electric currents. Wall. 12536.
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Wireless signalling systems. British Thomson-Houston Company. 12564.
Automatic telephone systems. Relay Automatic Telephone Company. 12673.
Systems of distribution for electrically-operated railway trains. Turner. 15303.

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Means for supporting and insulating electric lines. Bullers, Ltd., and G. V. Twiss. 1309.
Electric joint. G. H. Scholes. 1635.
Electric car lighting equipments. Albion Motor Car Company, and T. B. Murray. 3559.
Holders for incandescent electric lamps. J. Salt. 4575.
Means for telephonic communication to and from moving railway trains. V. G. Werner and K. H. Warfvinge. 6629 and 11397.
Telegraph transmitting apparatus. W. J. Mellersh-Jackson. 9193.

METAL QUOTATIONS.

TUESDAY, SEPTEMBER 19TH.

Aluminium ingot	—	per cwt.
,, wire, according to sizes, &c. .....from	—	,,
,, sheets ,, ,, ... ,,	—	,,
Antimony	£95/–/–	per ton.
Brass, rolled	1/3⅜	per lb.
,, tubes (brazed)	1/5¼	,,
,, ,, (solid drawn)	1/3¼	,,
,, ,, wire	1/2⅞	,,
Copper, Standard	£116/–/–	per ton.
Iron, Cleveland	87/6	,,
,, Scotch	—	,,
Lead, English	£32/–/–	,,
,, Foreign (soft)	£30/10/–	,,
Mica (in original cases), small	6d. to 3/–	per lb.
,, ,, ,, medium	3/6 to 6/–	,,
,, ,, ,, large	7/6 to 14/–	,,
Quicksilver	£17/12/6	per bottle.
Silver	32⅝d.	per oz.
Spelter (American)	£49/–/–	per ton.
Tin, block	£171/10/–	per ton.
Tin plates, I.C.	32/–	per box.
Zinc sheets	£72	per ton.

Exports of American Motor Vehicles.—The exports of American motor vehicles for the year ended June 30th last was 77,496 machines, valued at £19,700,000, compared with £12,000,000 in the preceding year. The number of commercial vehicles was 21,265, and passenger cars 56,231. Comparing the months of June, 1916 and 1915, it is interesting to note that there was a decrease in this year's exports amounting to £1,000,000, due no doubt in large measure to the import restrictions imposed by Great Britain on motor vehicles.

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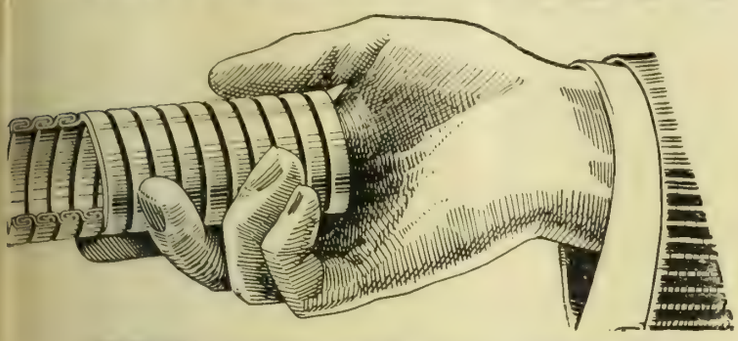

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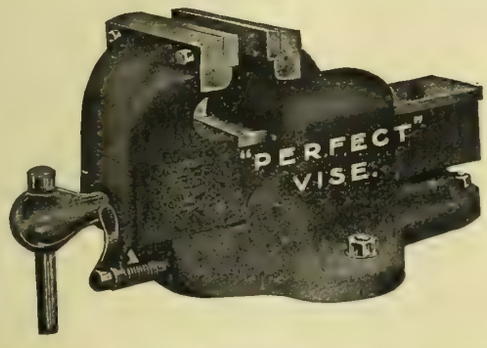

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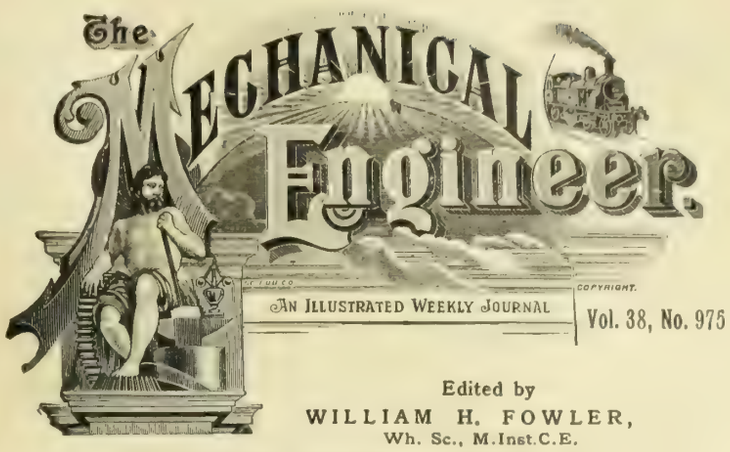

Edited by
WILLIAM H. FOWLER,
Wh. Sc., M.Inst.C.E.

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Labour Hours and Output.

THAT labour output cannot be measured simply by working hours is obvious to anyone who has held any responsible position of management in an engineering workshop, and for this reason the old trade union demand for an eight-hours' day for all ranks of labour, irrespective of its physical strain, has always seemed absurd. There are classes of labour in which continuous application for less than eight hours is quite sufficient to exhaust a man's energies, while there are others requiring only occasional attention such as the replacement of a piece of material or tool which a man can follow for 10 or 12 hours without undue fatigue. What is the most efficient length of working day to secure a maximum sustained output is one which can only be decided by observation and experience, and viewed in this light the White Paper issued last week, giving some statistical information gleaned by Dr. Vernon from observations of the output of munition workers is an interesting contribution Dr. Vernon divided the types of labour investigated by him into five classes, ranging from "very heavy" to "very light," the former being characterised as suitable only for men and the latter as inappropriate to them on account of its lightness. The data, though provisional, clearly justifies the conclusion that hours of labour should be varied within wide limits according to the nature of the work performed, and further, that women, even when engaged on the lighter classes of labour, are not capable of sustaining the strain as persistently as men. Though stern necessity may compel long hours of labour, it is evident that, provided the maximum output is maintained, the shorter the hours are the better the chance of health on the part of the worker. Hence everything should be done to speed up production so far as this can be effected mechanically without straining the physical energy of the operative. To this end it is suggested in the report that

greater promptness should be exercised in starting work, while at the same time short breaks of a few minutes might be introduced into the morning and afternoon shifts. Long unbroken spells of labour on work of a repetitive type become monotonous and wearisome, even though the labour be light, and output as a consequence falls. Some interesting results bearing on this point are given as a result of investigations made by Dr. Vernon at a particular works. Denoting the output of certain women on an average week of 68·2 working hours by 100, he found that when the hours were reduced to 59·7 the output, though it did not show an immediate increase, rose eventually to 123. He noted also as a curious effect, though it is probably in keeping with the experience of most of us, that the output increases in the period immediately preceding a holiday, falls immediately after it, and then rises considerably for a long term. Dealing with the results obtained from the same group of workers, it was found that while it is impossible to lay down exact rules, it could at least be asserted that to attain a maximum output the hours of women engaged in moderately heavy manual work should not exceed 60 per week, and that probably even a reduction to 56 hours would have no adverse effect on output, so that the latter figure should be regarded as the maximum for this type of labour. For women engaged on light labour 62 hours is regarded as the best. Turning to men engaged in heavy labour it was shown that after a reduction of 10·4 in the hours of work per week, the men succeeded after a little time in increasing their output to no less than 13 per cent. above the old hour rate, while in regard to youths the effect was even more marked after they had adjusted their efforts to the shorter hours, the output in 11 weeks after the hours of labour had been reduced from 70·3 to 57 being no less than 42 per cent., a clear indication that the former length of week was excessive. It would appear evident, in fact, from the tests made, that where heavy labour is concerned the greatest output is secured by a series of short spells. On the other hand, for men and youths engaged on light labour the experiments showed that to attain a maximum output 70 hours or more per week were necessary. In regard to all these results it should be pointed out that the maximum hours named were those for war conditions, and pertain only to strong and healthy operatives, who had proved their competence at munition work.

THE ECONOMICAL PRODUCTION OF POWER FROM COKE-OVEN GAS.

In a paper appearing in the June issue of the "Journal of the Institution of Electrical Engineers," Mr. G. Dearle discusses the subject of coke-oven gas engines, and describes a plant operated under his supervision. The installation consists of 300 b.h.p. to 500 b.h.p. vertical tandem gas engines, direct coupled to 3-phase alternators generating current at a pressure of 440 volts and a frequency of 50 cycles per second. The gas engines are of the single-acting type, 4 stroke cycle, the cylinders being so arranged that the suction stroke of one cylinder is the explosion stroke of the other cylinders on the same line. By this arrangement each crank receives one impulse per revolution, each down stroke being a working impulse of either the upper or the lower cylinders. On the up-stroke the inertia of the moving parts is absorbed by the compression of either the top or the bottom cylinder, and part of the inertia is absorbed on the downward stroke by the buffer cylinder formed under the upper piston. By means of this arrangement the connecting rod is always in compression, and little or no strain is thrown upon the connecting-rod bolts. This is an important feature, as, according to the reports of the various insurance companies, more breakdowns to engines are caused by the failure of these bolts than by any other cause. There are eight cylinders on each engine, the upper four having a diameter of 16·5in. and the lower ones 15·5in., with a stroke of 16in. The speed is 300 revs. per minute and the full load is 500 b.h.p. The object of making the upper cylinders 1in. larger than the lower ones is so that the whole line of pistons may be removed together; by this arrangement the dismantling of the engine for cleaning purposes becomes very simple.

The gas supplied is obtained from a battery of 110 Otto ovens; 60 of these are waste heat and 50 are of the regenerating type. From the former about 15 per cent. of the total gas is available and from the latter about 40 per cent. The average gas pressure is approximately 10in. The further purification of the gas after it leaves the by-product plant is very important. When the gas leaves the benzole scrubbers it contains about 900 grains of sulphuretted hydrogen in every 100 cub. ft. If this sulphuretted hydrogen were allowed to go through the engines, a considerable amount of trouble would be experienced. The moisture in the exhaust gases condenses as the engine cools down, and there immediately forms sulphuric acid which, in its turn, would attack the inside of the cylinders and the exhaust valves. A further effect is that the presence of sulphur causes a certain amount of pre-ignition of the charge during the compression stroke. A possible reason for this is that the presence of a small portion of the sulphuretted hydrogen acts as an igniter, it being more liable than the rest of the gas to spontaneous combustion under compression.

The gas is therefore purified by oxide of iron in a set of four purifiers of the Wilbourne type, each 20ft. square by 5ft. deep. The boxes hold about 30 tons of oxide in two tiers of ordinary grids. These boxes are worked on what is known as the "backward-rotation" principle. Air to the extent of 2½ or 3 per cent. is drawn in at the exhauster, and this air supply plays a very important part in the re-vivifying of the oxide in the purifiers; prior to the introduction of this air the oxide in the purifiers was changed at the rate of one box for every four weeks. After the introduction of the air, the period between the changes was extended from four weeks to four months. The total sulphur contained in the gas after passing the purifiers is less than 50 grains per 100 cub. ft., and the further advantage of the purifiers is that they eliminate absolutely the last traces of any tar which may be left in the gas after passing the benzole scrubbers.

During the initial running of the plant, some trouble was experienced due to the difficulty of obtaining satisfactory mixing of the gas and air. The usual method has been to dilute the mixture with a certain amount of exhaust gas. The writer considered this method somewhat inefficient and resorted to the following expedient: The main gas pipe to each engine was reduced for a distance of about 10ft. to an internal diameter of 2½in., and on reaching the engine was led into the mixing chamber for a distance of about 6in. Entering the mixing chamber at right angles to this pipe, and about 3in. above its end, was an auxiliary supply controlled by a diaphragm governor. The gas admitted through the mixing chamber was then diluted by a certain quantity of air. A further air supply, controlled by a hand lever from the driving platform, was led direct into the chamber of the governor valve where the diluted gas and air met. After passing through the chamber of the governor valve the mixture was given a rotatory motion by means of a set of vanes, and was also very thoroughly mixed by being passed through a set of perforated plates. With this device over-heating or pre-ignition were eliminated and the engines could be run up to and above their rated capacity without trouble.

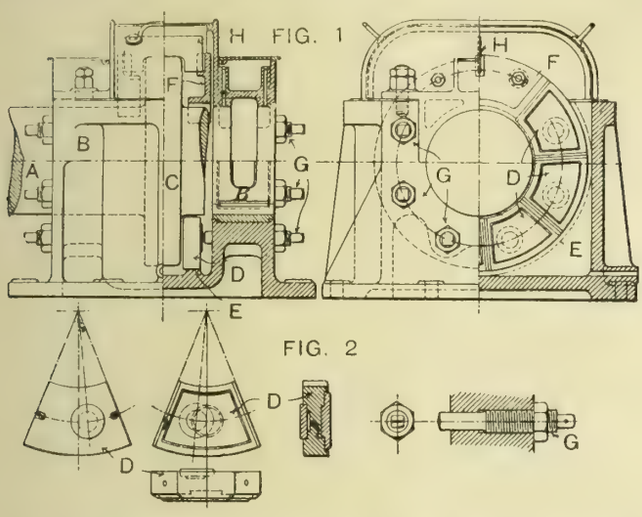
During March, 1914, a maximum of 15,000,000 cub. ft. was used. During that period the author had been unable to pay the necessary attention to the question of gas consumption. The matter was then taken up and by regular analyses of the exhaust gases combined with instructions to the drivers to drive by the pressure gauge, the gas consumption was reduced to 12,500,000 cub. ft. at the end of May, and was still further reduced later on, the load remaining approximately the same. The present consumption is approximately 39 cub. ft. per kilowatt-hour. For the most tried part of a gas engine of the type described, the exhaust valve, nickel steel was found to be the best material.

PRESSURE OIL FILM LUBRICATION.*

BY H. T. NEWBIGIN, A.M.INST.C.E.

THE primitive form of journal bearing is merely a hole bored in the frame of a machine in which a shaft revolves, and the primitive thrust bearing is only a collar or shoulder on a shaft to prevent it moving endways. These fulfil their function satisfactorily for many purposes, but as the rubbing speed increases, either due to an increase in the shaft diameter or an increase in the speed of its rotation, or both, it becomes necessary to devote more attention to the design of these machine parts, apart altogether from the effect of a reduction in friction on the efficiency of the machine as a whole.

Without lubrication a bearing will not run without excessive wear, and without artificial cooling no bearing with oil lubrication will run continuously if the temperature rises above 150° Fah., because at about this temperature most oils begin to carbonise. The efficiency of a bearing must therefore



be such that the temperature due to the heat generated by its friction, minus that dissipated by radiation and conduction, does not exceed this figure.

In order to reduce the friction between two rubbing surfaces it is necessary to put something between them, and bearings may be classified into those in which this is a hard material such as steel balls or rollers, or a viscous substance like oil or grease.

The first class does not consist merely in introducing balls or rollers between the relatively moving surfaces in the primitive forms of journal and thrust bearings, they are highly specialised machine parts designed to utilise to the greatest advantage the rolling action of balls or rollers in reducing friction, and their design is evolved from a study of this action. On the other hand (except in the cases to which reference will be made later), the second class consists merely in applying a lubricant to the primitive forms, or to some slight modification thereof. They are not designed to utilise the action of the lubricant on any principle, the lubricant is merely added to the primitive forms because it has been found to make them work better. Ball and roller bearings have attained to a remarkable degree of perfection, and they are admirably suited for bearings in which the loads to be carried are comparatively light, or in which the motion is intermittent, but they are not suited to carry heavy continuous loads, especially at high speeds.

In ball bearings the steel balls make point contact with hardened steel races, and the balls tend to flatten at the point of contact. Under excessive continuous loads this slight deformation of the balls causes their outer surface to shell off, the chips get under the other balls, and ultimately destroy the construction of the bearing. The life of the balls is limited, frequent renewals are necessary, and to effect these renewals it is essential to dismantle the bearing.

In roller bearings the rollers make (or are supposed to make) line contact with the housing and with the shaft. Although they are able to carry heavy loads, it is very difficult to maintain correct alignment, and any slewing of the rollers sets up a heavy end thrust against the cage in which they work. Furthermore, as the rollers bear directly on the shaft, the constant rolling action tends to laminate the surface and so wear it away. In roller-thrust bearings it is necessary to make the rollers conical, and as they therefore have a heavy radial thrust this type of bearing is not much used.

The great advantage of both ball and roller bearings is their low starting friction; for this reason they are especially suitable for intermittently moving machinery, but in continuously running machinery where a low starting friction is of less importance than a low running one, it is obviously a great advantage to have the rubbing surfaces separated by something more easily replaceable than either balls or rollers, especially if it is something that can be continuously replaced without stopping the machine, and the more so if it is also capable of being used in high-speed bearings as a medium for carrying away the heat generated by friction from the actual surface of its origin.

It is with the second class of bearings—those in which the surfaces are separated by a fluid such as oil in the case of high-speed and grease in the case of low-speed bearings—that this paper is more immediately concerned. The use of a lubricant for the purpose of reducing friction is very old, but the study of its action, and more especially the manufacture of bearings designed to utilise this action to the best advantage, is quite modern.

The action of a lubricant is twofold; it first of all alters the nature of the rubbing surfaces, thereby reducing friction (and this is the commonly accepted justification for its use), but under favourable conditions it goes much further than this and automatically generates a high-pressure oil film between the surfaces, entirely eliminating metallic contact and thereby enormously reducing the friction. This is what is now called "pressure oil-film lubrication." It occurs to a limited extent in most journal bearings, but does not occur in ordinary collar-thrust bearings.

The phenomenon of pressure oil-film lubrication was first noticed by the late Mr. Beauchamp Tower during the course of a series of tests he made in conjunction with the Institute of Mechanical Engineers in 1883 and 1885. He found, while experimenting with a journal bearing, that under certain conditions the rotation of the shaft was capable of dragging the oil adhering to it in between the surfaces to such an extent as to force the surfaces apart with a high-pressure oil film, and that the highest pressure in this oil film was about twice the average pressure. He also found that the highest pressure was on the longitudinal centre line of the brass and a little forward of the sectional centre line in the direction of rotation, and that from this point the pressure fell to zero around the edges of the brass. A bearing under these conditions runs with very much less friction than under any other, and will carry a much higher load.

Following on Tower's experiments, the late Prof. Osborne Reynolds, F.R.S., in a paper read before the Royal Society in 1886 on "The Theory of Lubrication," showed that the friction under the circumstances was merely that due to the viscous flow of the oil, and he showed how, by calculation based on the theory of viscous flow, a pressure curve may be obtained which closely approximates to that obtained experimentally by Tower. In his theory Reynolds made the assumption that the length of the bearing, *i.e.*, the dimension at right angles to the direction of motion, was infinite, and as this is never the case in practice, his theory was of little practical value and it did not lead to any alteration in the construction of bearings. From the practical point of view the most important things that he showed were: (1) That in order to obtain a pressure oil film between lubricated surfaces the surfaces must have a slight inclination to each other, with the opening at which the oil enters greater than that at which it leaves. Or, in other words, that the oil film must be wedge-shaped. (2) That in the case of a journal bearing the wedge form of the oil film occurs naturally, due to a slight shifting of the centre of the shaft in relation to the centre of the brass. (3) That such a wedge-shaped oil film cannot occur in a collar-thrust bearing; hence their inefficiency and low-carrying capacity.

It was left to an Australian engineer and mathematician,

* Paper read before Section G of the British Association at Newcastle, September, 1916.

Mr. A. G. M. Michell, of Melbourne, not only to complete Reynolds's theory, but also to show how its teaching can be applied in practice, to the vast improvement of both thrust and journal bearings. In a paper published in "Zeitschrift für Mathematik und Physik," in 1905, on "The Lubrication of Plane Surfaces," he gave the complete mathematical solution of Reynolds's theory as applied to plane rectangular surfaces. And on the assumption that the thickness of the oil film at the entering edge is twice as great as at the leaving edge, he showed how lines of equal pressure within the film can be plotted and how the centre of resultant pressure can be determined for plane rectangular surfaces of varying proportional cross dimensions. He also demonstrated practically that a rectangular block pivoted at its point of resultant pressure will automatically assume an angle to an opposing lubricated surface, depending on the speed of rubbing, viscosity of the oil, and pressure. On this principle he founded his now well-known thrust bearing.

The result of Mr. Michell's work has been to enable lubricated thrust and journal bearings to be designed with the principles of oil-film lubrication as a basis, in the same way as ball and roller bearings are designed with the ball or roller as a unit, and as distinguished from the mere application of oil to the primitive forms of these bearings. The essential feature of the Michell bearings is the sub-division of the stationary surface into a number of blocks or pads, each pivoted at its back, and so free to assume a slight angle with its contacting surface. Bearings designed on this principle differ radically from the primitive forms of journal and thrust bearings, but the results obtained in practice have fully justified the change.

Taking the case of the thrust bearing first, the Michell thrust bearing differs from the older type in having only one collar, the multiplicity of collars in the older type having been necessitated by the low carrying capacity of parallel rubbing surfaces, as distinguished from the high carrying capacity of those in which the fixed surface is sub-divided and made free to assume the angle to the opposing collar necessary for the formation of oil pressure within the film.

The importance of efficiency in machinery is not merely a question of economy of power or fuel, it also controls the practicability of a design, and the design of bearings is an example of this. For example, in the design of a large multi-collar thrust bearing (which is merely an elaboration of the primitive form) the problem the designer has to solve is governed by the efficiency of this form. He has given a shaft of a certain diameter, revolving at a certain speed, and which has to withstand a certain thrust. The resistance to turning will be about 0·03 of that thrust, and the greatest load that the bearing surfaces will carry with safety is about 50lbs. per square inch.

In order to bring the pressure down to this figure, he may either use a few collars of large diameter or a number of collars of small diameter. If he does the former, he increases the radius at which the friction acts, and so the power absorbed and the heat generated, and if he does the latter it becomes increasingly difficult to maintain an equal distribution of the load among the collars, especially under the variations of expansion due to the heat generated when the bearing is at work. Furthermore, whatever compromise he makes, there comes a point beyond which the size, load, and speed cannot be increased because, owing to the high coefficient of friction, the heat is generated more quickly than it can be dissipated by radiation and conduction, even with the aid of water cooling.

This point was reached in the case of the thrust bearings in geared turbine-driven vessels, and partly because the bearings were found to be less able to withstand thrust under the uniform turning movement given by this type of engine than under the varying turning movement given by reciprocating engines. It therefore became necessary to find a form of thrust bearing in which the coefficient of friction is lower than that in the primitive type.

The Michell thrust bearing, which goes to the root of the matter and is designed from the point of view of the action of the lubricant in automatically generating a pressure oil film between the surfaces, has formed a complete solution of the difficulty. It has a coefficient of friction of about 0·0015 as against 0·03, and carries 200—300lbs. per square inch with a much greater factor of safety than the primitive form has at 50lbs.

Test of Experimental "Michell" Journal Bearing, May, 1916.

Duration of test.	Total load.	Bearing pressure.	Revs. per min.	Surface speed.	H.P. input.	Oil supply. Final inlet temp. F.	Final outlet temp. F.	Rise of temp. F.	Flow of oil.	Friction h.p. from heat to oil.	Coefficient of friction.	Actual friction.
Mins.	Lbs.	Lbs. per sq. in.		Feet, min.		Deg.	Deg.	Deg.	Lbs., min.			Lbs.
45	—	—	585	1,840	9·2	68	84	16	12·6	1·9	—	—
105	2,400	145	620	1,950	7·9	79	99	20	14·8	2·8	0·0099	47·5
105	3,600	220	615	1,930	8·6	84	101	17	14·3	2·3	0·0054	39·2
60	4,800	290	605	1,900	8·6	83	100	17	15·6	2·5	0·0045	43·7
40	6,000	370	615	1,930	9·1	84	102	18	17·6	3·0	0·0043	51·6
75	7,300	440	607	1,907	10·0	84	102	18	18·7	3·2	0·0038	55·4
45	8,500	520	605	1,900	10·2	83	99	16	19·0	2·9	0·0029	50·1
60	9,800	600	618	1,940	10·9	71	93	22	19·0	4·0	0·0034	67·6
90	11,700	700	611	1,920	11·1	76	100	24	19·7	4·5	0·0033	77·2
30	14,800	900	620	1,950	14·4	77	102	25	22·7	5·4	0·0031	91·7
30	—	—	1,315	4,130	12·2	76	95	19	23·0	4·1	—	—
60	2,460	145	1,320	4,140	14·8	74	96	22	26·4	5·5	0·0091	43·7
45	5,500	330	1,320	4,140	15·8	77	104	27	25·2	6·4	0·0046	51·1
60	8,500	520	1,303	4,100	21·6	82	117	35	33·0	10·9	0·0051	87·5
60	11,700	700	1,324	4,140	26·0	76	111	35	37·3	12·2	0·0042	98·3
105	11,700	700	1,317	4,140	21·2	73	112	39	31·2	11·5	0·0039	91·2
30	14,800	900	1,320	4,140	24·7	76	117	41	33·0	12·7	0·0034	100·4

The sub-division of the fixed surfaces into a number of segmental tipping blocks or pads is the essential feature of all thrust bearings made on this principle, but there are many variations in the design of the housing and method of carrying the tipping blocks, depending upon the particular use to which the bearing is to be put.

Fig. 1 shows sectional side and end views of one form in which marine thrust blocks are made. The shaft A is supported in two journal bearings B, one on each side of a single collar C, which bears against two series of segmental pivoted blocks D, arranged in the form of two inverted horse-shoes, the one for "ahead" and the other for "astern" thrust. The blocks D—each of which is pivoted, somewhat behind its centre, on the ends of the screws G—rest on two ledges E, concentric with the shaft. They are prevented from rotating with the shaft by means of the stops F, by removing which they may be taken out without disturbing the adjustment of the screws G, or lifting the shaft. Fig. 2 shows a detail of one of the blocks D, and of its screw G. The body of the housing forms an oil well in which the collar revolves, and a scraper H is provided to scrape off the oil

brought up by the rotating collar for the purpose of lubricating the upper blocks. This type is self-contained as regards lubrication, and in the case of large sizes, or those running at a high speed, the body of the bearing is water jacketed. The friction is about $\frac{1}{25}$th of that in the multi collar type.

In the case of the thrust bearings in steam turbines the type adopted is somewhat different. The blocks are symmetrically disposed around the faces of the collar, and each series is mounted on a ring partly spherical on one face, the convex surfaces of which are outward and rest on correspondingly spherical seats for the purpose of automatically distributing the load among the blocks. The blocks are mounted on the faces of the rings next the two sides of the collar against which they pivot, either along radial lines or on rounded pins. This type is entirely enclosed and is supplied with an oil circulation by means of an independent pump. The oil passes through an oil cooler on its course, thereby removing the heat generated by friction from the actual surface of its origin. The mean rubbing speed sometimes exceeds 100ft. per second. Slow-speed bearings are made on the same principle, with grease lubrication.

Upwards of 800 Michell thrust bearings are now running in this country alone, in sizes varying from 1in. to 15in.

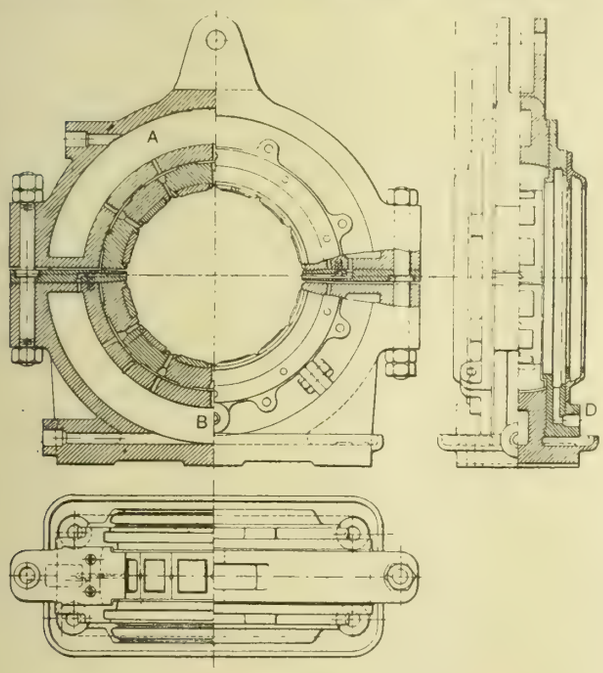


FIG. 3.

diameter of shaft, and larger sizes are in course of construction. The use of them is rapidly becoming the standard practice in steam turbine work. The same principle is now being applied to journal bearings. In lubricated journal bearings of the primitive type (as already stated) the phenomenon of pressure oil film lubrication occurs naturally, due to the slight shifting of the centre of the shaft in relation to the centre of the brass, but its occurrence is much less marked in the case of bearings of large diameters, probably owing to the greater oil clearance that is necessary in large sizes and to the extreme thinness of the oil film. For example, a journal bearing of 2in. or 3in. diam. will run satisfactorily under a pressure of 300lbs. to 400lbs. pressure per square inch, but it is not found advisable to load large bearings above 100lbs. even with a forced oil circulation.

The pressure oil film only occurs along a narrow strip in the primitive type, and the remaining surface merely forms a brake on the rotation of the shaft. So that the designer is again restricted and can only reduce the pressure to the limit found safe in practice by increasing the length of the bearing. But by sub-dividing the circumferential surface into a number of segments, each of which is pivoted at its back and thereby free to form an independent pressure oil film between its rubbing surface and the shaft, the number of the pressure oil films can be increased, so that the full projected surface of the bearings becomes effective for carrying load, and the brake surface is eliminated. The friction is thus reduced, the load-carrying capacity increased, and the bearing shortened.

A series of tests has recently been run on a Michell journal bearing at the works of Messrs. Cammell, Laird, & Co., Ltd., Birkenhead. Fig. 3 shows details of the experimental bearing. As will be seen from Fig. 3, the bearing surface is divided into 12 segments, each of which is pivoted on a rib at its back, so that it is free to lift at its leading edge to allow the necessary wedge-shaped oil film to form. The faces of the segments or blocks are lined with white metal, each surface being 2in. square, giving 48 sq. in. of rubbing surface, the equivalent projected area of each half of the bearing 16½ sq. in.

In addition to the segments being free to tilt, the seat on which they rest is partly spherical, thereby making the bearing also a swivelling one. A circulation of oil was passed through the bearing, entering it between each pair of blocks from the chambers A and B, and escaping at D. The bearing was driven by means of an electric motor, and the ammeter and voltmeter readings recorded. Each run was continued until the oil temperature ceased to rise. The ingoing and outgoing temperatures of the oil were also recorded, together with the weight of the oil passing, and the revolutions per minute. The load was applied by adding weights to the scale pan of a lever, the leverage being 11 to 1. The accompanying table gives the results observed, together with the friction calculated from the heat taken up by the oil. The friction is that for the two halves of the bearing pressed together. To get the coefficient of friction these figures require to be divided by twice the load.

STONE-DUSTING OF MINES.

AN interesting paper entitled "Notes on the Stone Dusting of Steam Coal Collieries," by Mr. G. D. Budge, was read at a recent meeting of the South Wales Institute of Engineers. The paper contains the results of an exhaustive series of tests on stone dusting, and as a result of his experiments the author has arrived at the following conclusions:—

(1) On many haulage roads, the dust film which is formed by particles carried in suspension in the atmosphere may accumulate in sufficient quantity to be dangerous in the period of 14 days. On parts of exceptionally dusty roads this accumulation may assume dangerous proportions in four days.

(2) All the dust raised in suspension in the atmosphere on a stone-dusted road (in the ordinary course of working) will pass through a 60 sieve; 95 per cent. of it will pass through a 90 sieve; and 77 per cent. of it will pass through a 180 sieve. It is therefore certain that only the finest of the stone dust comes into suspension under normal conditions.

(3) The greatest accumulations occur where the velocity of the air is high and where the speed of haulage is high.

(4) Most of the dust which enters the mine from the surface is deposited within 80 yards of the downcast shaft, probably because the area of the road near the pit bottom is generally large and the air velocity correspondingly low.

(5) If the journeys of coal are thoroughly sprayed before leaving double partings, and if the empty trams are similarly treated before coming down the pit, the dust raised from the top of the trams (and in the case of the empty trams, from the inside of the trams) is less in quantity than that raised from the floor.

(6) The floor dust on a dry haulage road loses its ash rapidly owing to leakage of coal dust from tram doors, and to the grinding of pieces of coal by the tram wheels. A very pure coal dust is found in the groove cut by the flange of the wheel on each side of the road. This dust is raised into the atmosphere in large quantities by every passing journey. Floor dust will generally become reduced in ash at the rate of 5 per cent. per week on roads dealing with 300 to 400 tons of coal per day if the gradient is 3in. to 4in. per yard and the speed of haulage is high.

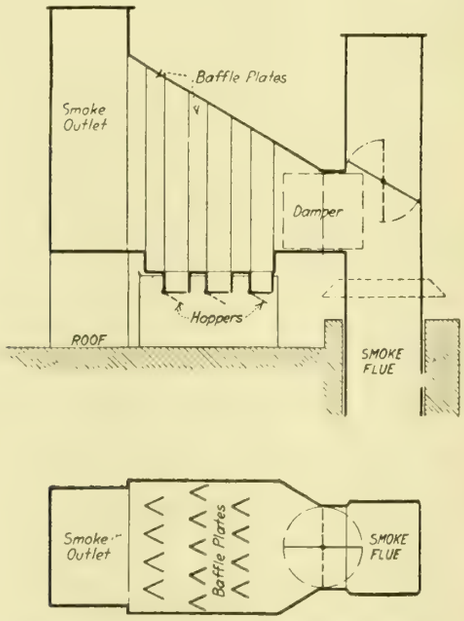
(7) If the floor of a haulage road be kept moist, and the roof and sides stone dusted, and if all full and empty journeys be sprayed, it is possible under average conditions to reduce the rate of accumulation of suspension dust to about 0·027oz. per square foot of road surface per week, even where the quantity of coal passing amounts to 300 tons per day. The suspension dust will not, however, maintain a high ash percentage over a long period, as when the floor is wet the deposit is formed chiefly of dust blown from the tops of the loaded trams. It will probably carry 27 per cent. of ash at the end of three months, being diluted to this extent by stone dust raised into the air from the roof and sides by the vibration and increased velocity caused by passing journeys.

(8) If the floor of a very dusty haulage road cannot be kept moist, but all journeys of trams are sprayed, the rate of accumulation of suspension dust will in many cases be 0·109oz. per square foot per week, where the quantity of coal passing amounts to 300 to 400 tons per day. When, on a road of this description, stone dust is laid in sufficient quantity to bring about a mixture on roof, sides, and floor of 60 per cent. incombustible dust to coal dust it will generally be found that the ash content of the suspension dust collected one week after stone dusting will average 40 per cent. If no further stone dust be laid, the ash content of the suspension dust at the end of four weeks will be reduced to 20 per cent., although the mixture on the roof, sides, and floor may still exceed 50 per cent. incombustible dust to coal dust. This serious decrease is due largely to the daily supply of fresh coal dust ground up by the tram wheels. It accumulates alongside of the rail, exactly in the same way as dust accumulates in the groove alongside of a tram rail in a street. In order to abate the dust nuisance in towns, this groove is swept daily. In a colliery the dust lodging in this groove can only be diluted (if water cannot be used), and by applying stone dust to the floor, close to each rail at the rate of 1lb. per yard of roadway per day, it is possible to maintain the ash percentage of the suspension dust at about 28 per cent. for eight weeks after the road was stone dusted.

(9) On haulage roads, where the velocity of the air is low, the speed of haulage moderate, the gradient not exceeding 3in. per yard, and where the conditions generally are against a heavy "make" of dust, the average deposit of suspension dust per square foot of road surface per week may be as low as 0·036oz. An application of stone dust at the rate of 30lbs. per yard on a road of this description has been found to maintain the dust on the roof and sides at 75 per cent. ash, and the suspension dust at 34 per cent. ash, after three months had elapsed from the time the stone dust was applied. The floor dust, however, showed only 32 per cent. ash at the end of the three months.

APPARATUS FOR REMOVING DUST FROM SMOKE.

A SIMPLE apparatus for removing dust from smoke was described in a paper read before the American Society of Heating and Ventilating Engineers. The apparatus is clearly shown in the accompanying sectional views, and consists of a



APPARATUS FOR REMOVING DUST FROM SMOKE.

large settling chamber provided with a set of baffles so arranged as to extract the maximum amount of cinders without creating an undue resistance to the flow of the gases. Some months ago the apparatus was installed at a plant and has given every satisfaction. The cinders are removed once a week from the hoppers below the settling chamber by means of the bottom cleaning doors shown. The actual amount of cinders obtained varies with the amount of coal used, as well as the percentage of ash contained in the coal. Ordinarily about 5 cub. ft. of cinders are removed weekly from the collector.

FUEL ECONOMY.

FIRST REPORT OF COMMITTEE APPOINTED BY THE BRITISH ASSOCIATION.

(*Concluded from page 221.*)

APPENDICES.

THE WORK OF THE SUB-COMMITTEES.

The following memoranda concerning the work of each of the five Sub-Committees will sufficiently indicate the various matters which are at present chiefly under consideration, and the arrangements which have been made for their future investigation.

A.

*Chemical and Statistical Sub-Committee.**—Dr. J. T. Dunn (chairman), Prof. P. P. Bedson, Dr. W. Galloway, Prof. Thos. Gray, Mr. T. Y. Greener, Prof. L. T. O'Shea, Sir Richard Redmayne, Dr. A. Strahan, and Dr. R. V. Wheeler.

The Sub-Committee is preparing a memorandum and a bibliography upon the question of the chemistry of coal, and is of the opinion that the time has now arrived for a re-investigation of the subject in order to clear up a number of outstanding points connected with the chemical constituents of coal, their mutual relations in the raw material, and their influence upon the character of the various products obtainable by its distillation or oxidation. Accordingly, some of its members have undertaken experimental work, partly on new lines and partly by way of check repetition, with the object of providing a basis for a more complete attack upon the subject in the near future. A group of research assistants is already working on the problem under Prof. Bone's direction in the Department of Chemical Technology of the Imperial College of Science and Technology, London.

As an important part of the work, the Sub-Committee hopes later on to organise systematic investigations upon the chemical character of the principal British coal seams. Such an undertaking would, however, involve considerable labour and expense, and the prospect of achieving any useful result will depend entirely on the amount of funds which may be forthcoming in support. The Sub-Committee is of the opinion that the resources, both of the existing laboratories which have been established within recent years in this country for the special investigation of fuel problems and of other laboratories where the technique of the subject has been developed, might be utilised more than they are at present in this connection, and that the time is ripe for the organisation of a scheme of systematic co-operative research, aided by national funds, in which all such laboratories may participate.

The Sub-Committee is also compiling statistical information relative to the different purposes for which coal is used, and has entered into communication with the Board of Trade upon the question, but the collection and analysis of such statistics has been greatly impeded by the war.

Another important matter into which the Sub-Committee proposes to enquire is the amount of wastage due to coal which, for one reason or another, is at present left behind in the pits. Part of such wastage, for example that due to the occurrence of faults in the coalfields, is unavoidable, but when all such allowance has been made, there undoubtedly remains a large wastage in working which might be and ought to be avoided. A memorandum is being prepared on the reduction of such wastage by the adoption of hydraulic stowing, a practice which, although in vogue on the Continent, has not yet been established in Great Britain.

B.

Carbonisation Sub-Committee.—Mr. T. Y. Greener (chairman), Prof. P. P. Bedson, Sir G. T. Beilby, Mr. E. Bury, Dr. Charles Carpenter, Dr. J. T. Dunn, Prof. Thos. Gray, Mr. D. H. Helps, Mr. C. H. Merz, Prof. L. T. O'Shea, Dr. J. E. Stead, Mr. G. Blake Walker, and Dr. R. V. Wheeler.

The total amount of coal carbonised in this Kingdom for the manufacture of metallurgical coke or for towns gas in the year 1913 was probably about 35 to 40 million tons, or approximately one-fifth of the total home consumption of coal for all purposes.

According to a recent Parliamentary Return relating to all Authorised Gas Undertakings in the United Kingdom, the

* The Chairman and Secretary of the General Committee are ex-officio members of each Sub-Committee.

total quantity of coal carbonised for towns' gas by 831 such undertakings in the year 1913 amounted to 16,971,724 tons, from which 195,826 million cubic feet of coal gas were produced, or say, on the average, about 11,500 cubic feet per ton of coal carbonised. There are a number of gasworks not included in this Parliamentary Return, and it is computed that they carbonise about one and a quarter million tons of coal per annum. Thus the total coal carbonised in gasworks throughout the Kingdom in the year 1913 would be about 18,200,000 tons.

The amount of ammonium sulphate produced by gasworks in that time in the United Kingdom was officially given as 182,180 tons, which on the above basis would represent an average yield of about 22·4lbs. per ton of coal carbonised.

No such complete returns are available in relation to the manufacture of metallurgical coke, but the amount of coal carbonised for this purpose in 1913 probably did not fall much short of 20 million tons. Of this coal, the larger proportion was carbonised in by-product ovens, producing, besides coke, tar, benzol, &c., some 133,816 tons of ammonium sulphate. Assuming an average yield of 22·5lbs. of ammonium sulphate per ton of coal, it would appear that approximately 13·3 million tons were carbonised in by-product ovens, and probably about half that amount in beehive ovens.

With regard to the coking industry, the Sub-Committee has already undertaken steps to secure a complete return of the number of by-product recovery ovens installed and working throughout the country, the character of each installation (whether waste heat or regenerative), its coking capacity, the description of the recovery plant connected with it (whether direct or indirect), the number of benzol recovery plants in operation, the quantities and yields of the by-products obtainable, and the purposes for which waste heat and surplus gas are being employed. When completed, this return will enable the Committee to arrive at an approximate estimate of the margins of possible economies in the shape of improved utilisation of the coal carbonised which can now be effected in the coking industry and the directions in which further progress is likely to be made.

A memorandum is also in course of preparation describing the more important developments of the by-product coking industry, from its inception until the present day.

With regard to gasworks practice, enquiries have been instituted regarding the present practice in connection with the manufacture of towns' gas, and for this purpose the Institution of Gas Engineers is officially represented on the Sub-Committee. It is also intended later on to consider the question of low-temperature carbonisation from the point of view of its possible economic results, but up to the present time so little authentic information is available that the Committee would welcome the offer of proper facilities to enable them to investigate the matter.

C.

Metallurgical, Ceramic, and Refractory Materials Sub-Committee.—Dr. J. E. Stead (chairman), Mr. Robert Armitage, M.P., Prof. J. O. Arnold, Sir Hugh Bell, Bart., Mr. E. Bury, Sir Robert Hadfield, Mr. Greville Jones, Dr. J. W. Mellor, Mr. Robert Mond, Mr. Bernard Moore, Mr. Benjamin Talbot, Mr. B. W. Winder, and Mr. H. James Yates.

The amount of coal consumed in metallurgical, ceramic, refractory materials, and cognate industries probably amounts to approximately 20 per cent. of the total home consumption. Of this, probably about three-fourths must be debited to the iron and steel industries.

The Sub-Committee has taken steps to ascertain from some of the larger manufacturers data which will assist it in determining the actual amount of fuel which is being used on the average in the manufacture of the various brands of pig iron, spiegeleisen, ferro-manganese, &c., throughout the Kingdom. A memorandum is in preparation concerning the heat balance of a blastfurnace of modern construction for the manufacture of Cleveland No. 3 and other pig irons, and a description will be given of the best methods now available for the utilisation of the surplus gases from such a furnace. Enquiries are also being made as to the results of the application of dry air to blastfurnaces.

In like manner a series of questions relative to fuel consumption in steelworks has been prepared for circulation among the larger steel plants in the Kingdom, with a view to ascertaining both the present average consumption and the directions in which further economies may be looked for in the near future. In this connection the Sub-Committee will endeavour to draw up a statement as to the best lay-out and arrangement of a combined by-product coking, iron-smelting, and steel-making plant from the point of view of utilising as completely as possible surplus gases and waste heat, and thus realising the maximum fuel economy in the heavy steel industry.

Similar enquiries will be instituted in regard to present-day practice and results in relation to (1) ironfoundries, (2) manufacture of wrought iron, and (3) specialised steel industries.

Two members of the Sub-Committee specially connected with the ceramic industry have undertaken to prepare a memorandum showing the average present practice and the possible margins of fuel economy in relation to that industry, and information is invited by the Sub-Committee relative to glassworks and brickworks.

The Sub-Committee desires to state that all information communicated to it by individual manufacturers will be regarded as confidential,* and will be used merely as a basis for arriving at an approximate estimate of the present average fuel consumption per unit of output in the particular industry to which the information relates.

D.

Power and Steam Raising Sub-Committee.—Mr. C. H. Merz (chairman), Lord Allerton, Mr. J. A. F. Aspinall, Dr. Dugald Clerk, Mr. S. Z de Ferranti, Sir Robert Hadfield, Dr. H. S. Hele-Shaw, Mr. W. W. Lackie, Mr. Michael Longridge, Mr. Robert Mond, Hon. Sir Charles Parsons, Prof. Ripper, Mr. R. P. Sloan, Mr. C. E. Stromeyer, Professor Threlfall, Mr. G. Blake Walker, and Mr. B. W. Woodhouse.

The special duty of this Sub-Committee is to investigate the economies in fuel which would result from the use of improved methods, and it has been decided to deal with the subject under the following heads:—

(1) To consider (*a*) the amount of fuel consumed, and (*b*) the corresponding power developed in the United Kingdom under the following heads: Factories, mines, railways, ships, and steam raising for other purposes than power.

(2) To consider the present position of central electrical power plants and gas undertakings as regards power supply.

(3) To discuss the relative merits of the present methods for producing power by steam, gas, oil, and petrol engines, respectively.

(4) To investigate the possible saving of fuel which might be effected (*a*) by improved plant, (*b*) by greater centralisation of power production, (*c*) by co-ordination with metallurgical and other manufacturing processes, (*d*) by some measure of public control, (*e*) by better supervision, and (*f*) by the use of inferior grades of fuel which are at present wasted.

While, on account of the magnitude of the subject and the amount of investigation involved, it is not possible at present to submit any report, it may be mentioned that information has been sought as to the amount of fuel consumed and the corresponding power developed in such official publications as the Report of the Royal Commission on Coal Supplies in 1905, the Census of Production for the year 1907, and the Returns published annually by the Home Office for Mines and Quarries, and various shipping and Customs reports. But although, from such sources, fairly accurate figures can be obtained for the amount of coal used annually for industrial purposes and shipping, the corresponding figures of power produced are not obtainable from any published returns so far as can be ascertained.

The average figure of 5lbs. of coal per horse-power-hour which was given in the Report of the Royal Commission on Coal Supplies in 1905 was, we believe, deduced from returns from a number of typical industrial concerns where information could be obtained, and it is probable that this estimate did not exaggerate the actual coal consumption per horse-power-hour at that time.

In view of the impossibility of obtaining accurate returns of fuel consumption per horse-power-hour from the whole of the power users in this country, it has been decided to investi-

* All such information should be sent in the first instance to Prof. Bone (Chairman of the General Committee), at the Imperial College of Science and Technology, London, who will classify and summarise it under either alphabetical letters or numerals in such a way that the names of the manufacturers or firms concerned will not be divulged to any of the members of the Committee.

gate the matter by asking for detailed returns from typical factories in various trades and in different districts throughout the country, selected by members of the Sub-committee who have special knowledge of particular trades.

Special memoranda are in course of preparation on questions of organisation of power production for industrial and transport purposes, the use of large turbine and gas engines, and other important aspects of the power question.

Domestic Fuel Sub-Committee. Mr. E. D. Simon (chairman), Mr. A. H. Barker, Prof. H. B. Dixon, Prof. W. W. Haldane Gee, Prof. W. P. Wynne, and Mr. H. James Yates.

The amount of coal actually consumed for domestic purposes in the United Kingdom probably does not fall far short of 36 million tons per annum—nearly one-fifth of the total consumption for all purposes in the Kingdom. To this would have to be added the "coal equivalent" of the gas and electricity consumed for domestic purposes, if a correct estimate of the total domestic coal consumption is to be made. The Royal Commission of 1905 estimated that 50 per cent. of the coal consumed for domestic purposes might be saved by the installation of better appliances, so that there is clearly a vast field for economy.

The whole question of domestic uses of fuel bristles with difficulties and complications. In the first place, it is necessary to discriminate between fuel or energy consumed in the kitchen for cooking and other similar purposes, and that applied for the heating of ordinary living-rooms.

In the vast majority of the houses inhabited by the artisan population the kitchen fire or stove is the only place in the house where fuel is burnt; also in better-class houses it is only in the kitchen that fuel is burnt daily throughout the whole year. Hence it would appear that the kitchen is responsible for the greater part of our annual domestic fuel bill, and therefore the question of the relative efficiencies of kitchen ranges, gas and electric cookers, and hot-water supply apparatus assumes considerable importance.

Again, the selection or recommendation of particular means or apparatus for domestic heating cannot always be based simply upon the question of thermal efficiency, because it also involves considerations of a physiological and even of a psychological character. Thus, for example, systems of central heating which have been recommended on grounds chiefly of thermal efficiency, and which are so universally used in America and on the Continent, are not usually acceptable to the average Englishman, who undoubtedly prefers to be warmed by the radiation from a bright fire.

This being so, the Sub-Committee feels that it will be wise to recognise at the outset that there is probably no single solution of the domestic heating problem which is likely to be universally adopted within any measurable period of time; and that, therefore, it should preferably concentrate its efforts upon questions of more immediate practical importance.

It will be generally agreed that any reform in domestic fuel consumption should aim at achieving one or more of the following objects, namely:—

(1) Actual reduction in cost of domestic heating, either in the form of direct saving of fuel or labour, or both;

(2) Mitigation or abolition of the domestic smoke nuisance; and

(3) Better hygienic conditions in living-apartments generally.

The Sub-Committee can perhaps best discharge its duties by considering how far the various systems now available for domestic heating fulfil such requirements, and how they may severally be installed and operated to the best advantage.

In order to do this the Sub-Committee has arranged for experiments to be carried out with the object of determining how to produce in a given room suitably warm and healthy conditions at a minimum cost and with a minimum production of smoke, and how such conditions may be defined for any particular room. Also, experimental work is being carried out upon the relative efficiencies of coal fires, gas fires, electric heaters, and the like.

Inasmuch, however, as in this country the use of the open coal fire will probably continue for some time to come, and as there are undoubtedly great economies to be immediately realised by the wider adoption of improved fire-grates, the Sub-Committee will pay special attention to the question of improvements in the construction and installation of such grates, to which the attention of architects, builders, and the public generally ought to be drawn.

Arising out of the present extensive use of solid fuel in domestic fires, the Sub-Committee will also consider the important question of the prospects of substituting for raw coal some form of carbonised fuel (semi-coke or coke). There can be no doubt but that if such a substitution could be effected, without either increasing the domestic coal bill or involving some other disadvantage, not only would there be a great addition to the amount of valuable by-products annually obtained from coal consumed in the Kingdom, but also the smoke nuisance in our large centres of population would be materially reduced.

Work on these lines is being carried out in the Department of Heating and Ventilating Engineering at the University College, London, at the Municipal School of Technology, Manchester, and at the Department of Chemical Technology at the Imperial College of Science and Technology, London.

NEW PROCESS FOR MELTING STEEL SCRAP.

OUR American contemporary, "The Iron Trade Review," gives particulars of a new process of melting steel scrap, the object of which is to produce metal free from oxide and blowholes, with a minimum loss of the metal constituents. The process, which has been patented by Albert E. Greene, Seattle, assignor to the American Smelting and Engineering Company, St. Louis, differs from most of the previous methods used to secure steel free from the presence of oxides of iron and manganese in that it acts as a preventative against injurious effects during the melting of the steel scrap rather than attempting to offer a means of remedying the undesirable effects after they have been embodied in the metal. The usual remedy for dissolved oxides is to add deoxidising alloys at the time of tapping the heat so that there will be as little time as possible for the absorption again of more oxides from the slag. The Greene process, it is claimed, eliminates excessive loss by oxidation by the use of a slag which prevents oxidation by the action of a reducing agent. In describing his method, Mr. Greene considers a case where ordinary steel scrap, carbon, 0·25 per cent.; silicon, 0·35 per cent.; and manganese, 0·70 per cent., is to be melted. For this purpose a basic-lined electric furnace is used in which a small amount of steel is introduced either by melting or else by charging in the molten state. A slag is then melted on top of the metal, for example, a lime-silica slag, the necessary fluidity being obtained by combining with the basic oxide of lime, an acideous oxide such as silica. This fluid slag readily covers the entire bath of molten metal and makes possible quick-reducing action on the oxides that collect in the slag. A fluid slag, it is said, also serves to keep solid carbonaceous reducing agents from contact with the steel, preventing a recarburisation of the metal. It is necessary, however, to provide the reducing agent in a reasonably fine state so that chunks of it will not dip through the slag and come into contact with the steel. After a suitable slag has been prepared in the furnace, the scrap is charged and fine coke is thrown upon the slag. During the melting of the scrap, fine coke or another form of reducing agent is added as conditions require. In this process, the silicon and manganese and the iron may be prevented from oxidisation. When the bath is reduced to the state where it is free from oxide of iron, the steel is then in a deoxidised condition and is ready to pour as soon as the temperature is properly regulated. The amount of reducing agent necessary to bring the slag to a reduced condition depends upon the oxides which enter with the metal. The colour of the slag is an indication of the extent of reduction. Instead of a solid reducing agent, a reducing gas such as producer gas may be readily employed with satisfactory results.

The Heroult Electric Steel Furnace.—According to "The Iron Age," the United States Steel Corporation has granted licenses for the installation of four more Héroult electric steel furnaces, there being a 2-ton furnace to the Warren Steel Casting Company, St. Louis, and three 6-ton furnaces to the Alabama Power Company, Anniston. These four furnaces bring the number of Héroult furnaces in operation or contracted for in the United States and Canada to 76.

CADMIUM IN SPELTER.*

BY WALTER RENTON INGALLS (U.S.A.).

FOR some purposes cadmium in spelter, even a small percentage of it, is deleterious. In spelter that is to be used for slush castings there is no doubt about it. In spelter for brass making there is not the same certainty. For brass that is to be cast and machined the adverse effect of cadmium is probably overestimated, and it may not be adverse at all. For cartridge brass it is objectionable. In many cases where cadmium is objectionable it is not unlikely that there is hair splitting about hundredths of a per cent. that is unnecessary. Military engineers and others who specify respecting brass should look carefully into this. The extraordinary differences in price that have lately prevailed, and still do to a less extent, between what in America are classified as high-grade, intermediate, brass-special, and prime western (common) spelter do not look right.

The sampling of spelter is more or less of a haphazard process and has a bearing on this subject. American brass-makers follow a time-honoured practice of sampling a carload (about 50,000lbs. of spelter in 820 to 960 slabs) by drawing 10 slabs at random, and that practice has within a few weeks received the official endorsement of the American Society of Testing Materials. This was the outcome of controversies that have arisen over that matter. The following, from an editorial by the writer,† may be appropriately quoted here:—

"An interesting and entirely friendly controversy respecting the proper sampling of spelter recently arose between a well-known seller and an important brass manufacturer. The seller agreed to furnish two carloads of brass special spelter guaranteed to contain not more than 0·6 per cent. lead. The cars having arrived at the buyer's works, he drew 10 slabs from each and finding the assays to exceed slightly the stipulated lead content called for an adjustment. The seller sent out the agent of a prominent firm of public assayers to draw a new sample of 30 slabs per car. The buyers refused in advance to abide by the result of this.

"The issue was clear-cut. The seller claimed that he should be required only to deliver a carload of spelter whereof the average should conform to the guarantee, that in determining the average a large sample is more desirable than a small one, and that the conditions of producing spelter do not permit the insurance of uniformity in slabs except in the case of high-grade spelter.

"The buyer, on the other hand, contended that the conditions of brass-making whereby the spelter is introduced into the melting pots in small lots necessitate uniformity, that its method of sampling during many years had been to draw only 10 slabs at random out of a carload, and that no other system would be safe for it.

"On none of these points have there been any official rulings. The specifications of the American Society for Testing Materials require as to sampling only that at least 10 slabs shall be drawn. In the contract between buyer and seller in this case, and probably in most of such cases, there was no contractual understanding.

"In the present instance the assays were made with the following results, those marked B being made by the buyer, and those marked S by the public assayer acting in behalf of the seller:—

Party.	Car.	No. Pieces.	Lead, per cent.	Iron, per cent.
S	1	30	0·491	0·013
S	1	12	0·644	0·012
B	1	10	0·737	0·013
S	2	30	0·758	0·021
S	2	12	0·616	0·023
B	2	10	0·667	0·021

"The interesting thing about these assays was that in the case of Car 1 the 30-slab sample showed lower lead than the 10-slab, while in the case of Car 2 it showed higher. The discrepancy between the 10-slab and the 12 slab samples is also noteworthy. Manifestly there was irregularity in the composition of the slabs.

"As to the merits of the case there is a good deal to be said for each side. The brass-maker needs uniformity of the product he is buying. On the other hand, the smelter can hardly ensure it by his present methods unless he be distilling high grade ore that is already uniform. In distilling ore containing lead, the proportion thereof that goes over with the zinc is governed primarily by the temperature of the retort which varies in different parts of the furnace. In drawing the spelter, the kettle into which it is received holds but a relatively small quantity, and the respective pourings from the same drawing may easily vary in composition, especially when lines are drawn so narrowly as they are as to lead content.

"Apparently there are two things that need to be done: (1) Sellers in offering a guarantee should specify as to whether it pertains to average of a carload or to any 10 slabs selected at random. (2) If buyers must have uniformity, smelters must ensure it by pouring and mixing their product in large pots or melting furnaces before casting the slabs to be marketed."

It need only be added that if the zinc smelter be obliged to guarantee practically every slab of his production, the consumer must pay for it; or if he must introduce the new process of re melting and mixing that also must be paid for.

Now, what are the conditions of the zinc smelter with regard to making spelter low in cadmium? His conditions are easy only when his ore is free from cadmium, but the only ore of that class produced in large quantity anywhere in the world is that of the Franklin mine of the New Jersey Zinc Company. That ore is also free from lead, and that company is the only one that can produce high-grade spelter by a single and simple process of smelting. The bulk of the world's zinc ore contains cadmium, and that metal being metallurgically similar to zinc distils with the zinc and contaminates the spelter, as also does lead.

In America, brass-special spelter is made by reserving the first of the three daily drawings of spelter. This metal having been distilled before the furnace has attained its maximum temperature is relatively low in lead, but in it there is a concentration of cadmium, which being volatile at a lower temperature than zinc comes over chiefly in the first stage of the distillation. Theoretically, it should be possible to control the temperature of the distillation so as to cut off both the cadmium-bearing spelter and the lead-bearing spelter, obtaining a high-grade spelter between, but practically that would be quite out of the question. It is, however, easily possible to get a high-grade spelter, low in cadmium, by the redistillation of common spelter with proper control of the temperature and separation of the first distillate.

A good deal of the high-grade and intermediate spelter that America has sold to Great Britain at fancy prices during the last 18 months has been redistilled common spelter. Great Britain ought to have bought common spelter and redistilled it herself.

In conclusion, it may be remarked that the electrolytic process of zinc extraction affords an easy means for the separation of cadmium. It should be borne distinctly in mind that the electrolytic process is going to be commercially applicable only under some limited specially favourable conditions, and is not going to drive zinc smelting out of the world's arts. However, the electrolytic zinc production that is likely to endure should go a long way towards meeting the demand for high-grade spelter, and especially spelter low in cadmium. And, furthermore, inasmuch as the electrolytic cathodes have to be remelted in large furnaces, the slabs cast therefrom should be more uniform in composition than those coming from the small tapping kettles of the retort furnace, the Bertha and Horsehead brands excepted.

* Paper read before the Institute of Metals, September 20th, 1916.

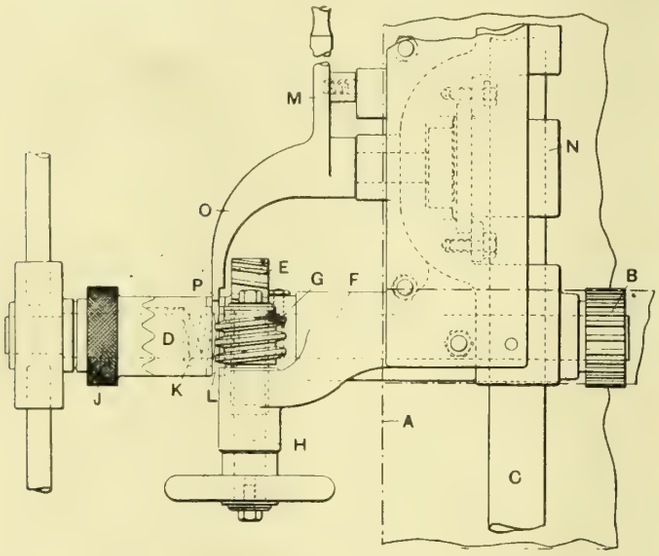
† "Engineering and Mining Journal," July 8th, 1916.

FEED MOTION FOR MACHINE TOOLS.

IN machine tools having a carriage or saddle slidably mounted on a bed and arranged to be traversed along such bed either automatically, or by the operator by irreversible gearing which provides a slow hand feed, damage may be inflicted on some of the carriage-operating mechanism if the automatic or power-driven feed is put into operation when the irreversible gearing is in driving connection with the carriage and vice versâ. With a view to obviate this, Mr. J. Holroyd, Fairfield House, Ovenden, near Halifax, has designed and patented the arrangement

illustrated which is shown applied to a lathe by way of example.

Referring to the illustration, A indicates the position occupied by a portion of the carriage or saddle, B the pinion for traversing the same by hand, and C the leading screw. A worm wheel E is rotatably mounted on the carriage pinion shaft F and gears with a worm G driven from a hand wheel on a shaft H. The worm wheel E is provided with means for preventing its endwise movement on the pinion shaft F, and is formed on one face with clutch teeth. Slidably mounted on a key on the pinion shaft is a clutch member D having teeth on one face to engage the clutch teeth on the face of the worm wheel, and on the other face teeth to engage similar teeth on a collar J that is rotatably mounted on the pinion shaft and provided with a milled surface for turning purposes. The projections on the clutch and collar are normally retained in engagement by a spring K which also



FEED MOTION FOR MACHINE TOOLS.

normally retains the teeth on the clutch member D and the teeth on the worm wheel E out of engagement. When the collar J is turned to cause the teeth thereon to ride upon the teeth on the clutch member D, the latter receives endwise movement and brings its other set of teeth into gear with the teeth on the face of the worm wheel E and such teeth are retained in gear by the flattened ends of the teeth resting one upon the other. When the collar J is turned to disengage the flattened ends of the teeth the spring K disengages the teeth on the sliding clutch member from the teeth on the worm wheel E and the latter becomes loose upon its shaft. When the parts are in this position a space L exists between the teeth as shown, and this space may be utilised in the following manner. Projecting from a hand lever M which opens and closes the half nuts N appertaining to the leading screw C is an arm O having a finger P that is just capable of entering such space and allowing the lever to turn and close the half nuts upon the lead screw. In this position the lead screw is operatively connected with the carriage A, and the worm gearing is out of operation and cannot be put into driving connection with the carriage. To do this the finger P must first be moved out of the space L, and in making this movement the lever is turned to a position in which the half nuts disengage the lead screw. The milled collar J is now turned to engage the teeth on the sliding clutch member D with the teeth on the worm wheel E until the flattened ends of the teeth engage as previously described. In this condition the lever that controls the half nuts cannot be moved to close the latter upon the screw, and the finger P prevents such movement of the lever by coming into contact with the periphery of the sliding clutch member D.

U.S. Exports of Aeroplanes.—American aeroplane exports for the fiscal year ended June 30th, 1916, were 269, against 152 to June 30th, 1915, and only 34 to June 30th, 1914. The value of the exports of aeroplane parts for the fiscal year ended June 30th was about £1,000,000.

SOME PROPERTIES OF INGOTS.*

BY A. W. AND H. BREARLEY.

Crystalline Structure and its Effects.—When steel, or any other crystalline substance, is cast into a mould the freezing commences from the inner surfaces of the mould, supposing the substance is quite fluid to begin with. Assuming the mould to be made from cast iron, and its cross-section a square, then freezing in any plane occurs more rapidly at each of the four corners than elsewhere; and the crystals lying in and about the corners, in consequence of the rapid cooling, are comparatively small ones. Crystals grow also from the sides of the mould, but as their growth sideways is hindered by the adjacent crystals, and their growth forward into the fluid mass is less restrained, they become long and narrow in shape. The crystals growing from any one side of the ingot mould, presuming the interior mass remained fluid, meet crystals growing from the adjacent sides, and a boundary to the cooling effect of each side of the mould is visible on a polished and etched specimen, or on a fractured surface, as junction lines lying diagonally on the square.

In the same way from the bottom of the mould, which is assumed to be flat, crystals grow also upwards until they meet those crystals growing from the sides of the lower part of the mould. It is easy to realise that crystals growing thus from a surface at right angles to the rest would meet obliquely on planes which outline the form of a four-sided pyramid. In the same way the cooling effect of the atmosphere on the free upper

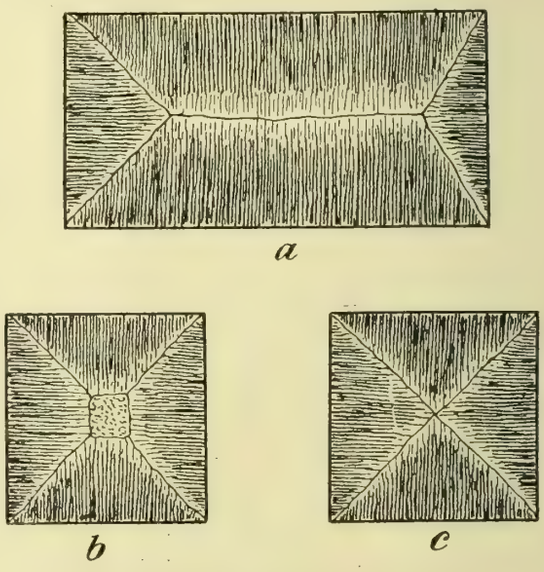


FIG. 1.—DIAGRAM OF CRYSTAL GROWTH IN INGOTS.

surface would cause crystals of the same narrow kind to grow downwards until they also terminated on the surfaces of a four-sided pyramid, assuming, of course, that the fluid material froze quickly, and was not disturbed at the upper end by shrinkage cavities or segregation effects. These considerations enable us to make a sketch diagram illustrating the arrangement of crystals as seen in any longitudinal section cut axially and parallel to a side of the mould (Fig. 1, *a*); in a cross-section cut at right angles to the axis of the ingot, near the bottom (Fig. 1, *b*); and in a similar section cut nearer the middle of the ingot (Fig. 1, *c*).

The diagonal lines in Fig. 1 are lines of extreme weakness; partly because they are lines of contact between crystals growing in different directions to each other, and partly because they are coincident with the intersection of the plane surfaces in the ingot which at successive moments were the last to solidify; consequently the planes are rich in segregates and non-metallic impurities (if such, as in steel, can possibly form), they are likely to be occupied by elongated gas cavities, and are also in the position where small cavities caused by contraction stresses would form. The influence of segregate plus contraction cavities would account for a great deal of the observed weakness along the diagonal planes, and it is not possible, apart from this influence, to determine how much of

* Abstract of paper read at the autumn meeting of the Iron and Steel Institute, September, 1916.

the observed weakness is due only to the crystalline arrangement.

These general observations can readily be verified and illustrated by means of ingots cast with molten stearine. As we have formed a very high opinion of the use of stearine for this and other similar purposes it is desirable at this stage to refer to the very natural prejudice against applying to steel ingots deductions drawn from the behaviour of stearine. To make experiments with steel is no doubt the most reliable way of learning about the changes which occur during the casting and solidifying of steel ingots; but it entails a costly plant, and molten steel is an expensive material and also dangerous when handled by other than experienced persons. There is also no method of determining the temperature of molten steel with satisfying accuracy, and finally, when ingots are made in the predetermined ways the cutting or breaking of them is both lengthy and costly.

With a few pounds of stearine, a pan of water, a beaker, a bunsen burner, a few tin moulds, and considerable patience, a great number of observations can be made to illustrate, extend, and also, in some respect, to correct prevailing notions about steel ingots. To increase your respect for observations along these lines and cautious interpretations thereof I need refer only to the very striking operation of removing the base pyramid. Those engaged in making ingots for the manufacture of ordnance are aware that for some years it was usual in many works to cut discs from the ends of ingots or billets and after polishing to etch them. On many such discs the etching revealed a ring of white spots which were really ferrite areas segregated about slag globules. The nearer the base the disc was cut the larger the ring of white spots, which was quite natural on the assumption that the white spots represented the outline of a section cut through the base pyramid. Though the white ring appeared frequently during the few years such observations were being made, no steel maker, within our experience, would admit that a well-formed cone, such as could be dislodged from a stearine ingot, could ever exist in a steel ingot. Eventually, however, a steel ingot weighing about 8cwt. was cast in such a way that it was held fast at each extreme end. When cooled under such conditions the ingot naturally cracked across the weakest part, and produced a cleanly separated cone.*

In a round ingot the crystals growing from the bottom of the mould are formed into a cone, and in an octagon ingot they form an eight-sided pyramid. In each case the base pyramid is longer or shorter, depending upon the cooling effect of the bottom in relation to the cooling effect of the sides; but generally the base exerts its full effect, because it remains throughout in direct contact with the freezing ingot, whereas the sides of the ingot, soon after solidifying, leave the mould and are thereby partly insulated from its cooling effect by a gaseous envelope. In many cases the pyramid may be separated intact from stearine ingots by pressing a knife into the ingot at right angles to its axis, and splitting layer after layer of the crystals until the peak of and ultimately the entire pyramid is disclosed. It is instructive by similar means to take ingots to pieces, as it were, in order to observe the effects of segregation and shrinkage cavities localised on their interior surface.

The growth of the elongated crystals originating at the surface of an ingot mould depends on circumstances, which appear to be somewhat contradictory, *i.e.*, they are favoured sometimes by slow cooling and sometimes by rapid cooling. So long as the fluid in the interior of the partly solidified ingot remains quite liquid, the crystals already growing from the sides of the mould increase in length as the temperature of the liquid about their extreme ends fall to freezing point. The act of freezing liberates heat, which is either stored up in the fluid or dissipated viâ the solid crystals, through the sides of the ingot mould. If the crystals are bad conductors of heat the cooling is necessarily slow, whatever the properties of the ingot mould may be, and the fluid in the centre of the ingot remains clear almost to the last drop, whilst needle-like crystals extend to the centre.

But if the crystals themselves are good conductors of heat, then the heat liberated as they form and also the heat from the fluid interior is rapidly dissipated through them. In this way the temperature of a large volume of fluid may reach its freezing point in many places simultaneously, before the crystals growing from the sides can extend to the centre, and thus the interior of an ingot would consist of crystals which had grown from independent centres and were developed in haphazard ways in all directions.

Of crystallisable substances, therefore, which are clearly liquid when cast, those that are very poor conductors of heat will form crystals of the same kind from the surface inwards if allowed to cool undisturbed. But steel, on the other hand, which is a good conductor of heat, will form crystals of the same kind from the surface to the centre of the ingot, only if the cooling takes place very quickly or very slowly. In the former case the crystals grow into the clear liquid and extend themselves rapidly as its temperature falls to freezing point; the result being thin crystals. In the latter case, however, the cooling is so slow that, owing to its high thermal conductivity, the temperature of the fluid mass becomes practically uniform throughout, and then a crystal is as likely to start growing in one place as in another, the result being irregular and approximately equiaxial crystals.

The considerations in these last two paragraphs are closely bound up with the question of casting temperatures, which will be discussed later. But meanwhile it may be said that the elongated crystals occur most frequently in steel cast in chill moulds of narrow section, and the equiaxial crystals in steel cast in dry sand moulds. Obviously there exists a great number of instances where both kinds of crystals occur in the same ingot.

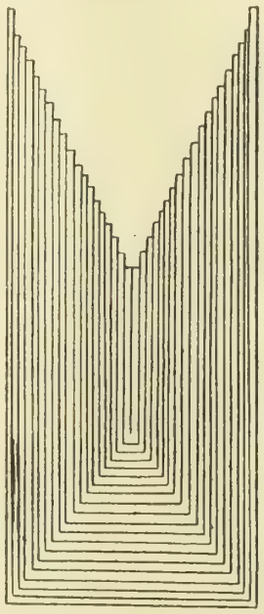


FIG. 2.—DIAGRAM TO ILLUSTRATE FREEZING OF INGOT IN STRAIGHT-SIDED MOULD.

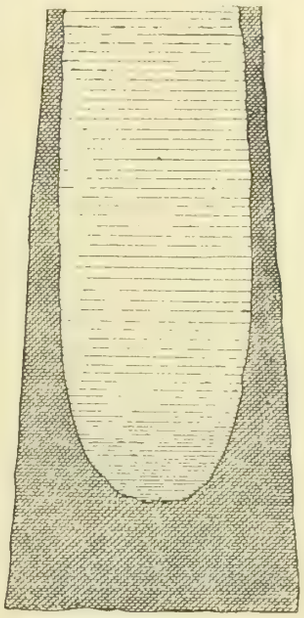


FIG. 3.—USUAL REPRESENTATION OF A FREEZING INGOT.

Shrinkage and Contraction Cavities. If we imagine an ingot mould filled with fluid material that could be cooled with perfect uniformity down to its freezing point, we should find that the level of the fluid would gradually sink as the fluid cooled and shrank. If at this point the fluid were to solidify instantaneously without change of volume we should have a solid ingot. But neither stearine or steel behave in this manner, and cavities due both to shrinkage of the fluid and contraction of the solid materials exert a great influence on the economic production of ingots, and have to be reckoned with.

An ingot just cast consists of a thin layer of solid metal with a fluid interior whose temperature, we may assume, is practically the casting temperature. The outside length of the ingot has been fixed by the thin solid envelope extending downwards from the highest level of the molten metal in the mould. After a little while the solid envelope has thickened, say, by a millimetre, but before that occurs the fluid metal has cooled, and owing to shrinkage does not now stand at the same level. This has been represented in Fig. 2 by a step down between the first and second millimetre in thickness of the freezing envelope. This process may be thought of as repeating itself in sucessive and distinct stages

* This experiment was made at the works of Messrs. Thomas Firth & Sons, Ltd.

as long as any fluid remains in the interior of the ingot, and as a result the central cavity or pipe would be as represented in Fig. 2. As a matter of fact Fig. 2 does represent the general outline of all central pipes in ingots cast in moulds having parallel sides. It differs from an actual pipe only because the thickening of the solid envelope is a continuous process and not an intermittent one; and also because the contraction of the solid envelope and the cooling effect of the atmosphere on the upper surface of the ingot must also be taken into account.

That the freezing of an ingot takes place by a continuous thickening of the solid envelope in planes parallel to the cooling surfaces of the solid is not unanimously admitted. The illustration given in Fig. 3 has been reproduced and approved as a representation of the freezing of steel ingots. It is, however, so far as the authors' observations go, a misleading representation of steel ingots and an inaccurate representation of the freezing of any crystalline substance, metallic or otherwise.

If a series of stearine ingots are cast simultaneously from, say 65° C., in square moulds, in all respects identical and widely spaced apart so that each cools freely, then on piercing the top and inverting one of them after 15 minutes and a further one after each additional 15 minutes, we are left with a series of shells of gradually increasing thickness, but in each case the shape of the cavity out of which the fluid wax was emptied corresponds to that made by the inner walls of the mould.

The same fact can be demonstrated in a more elegant manner by gradually planing down a single ingot parallel to one of its faces. After a few strokes with the plane the sectioned surface exhibits an envelope lying around it. The thickness of the envelope increases as the planing proceeds just as it did when the ingot was freezing, but it remains quite symmetrical in all parts. Also it thickens parallel to the cooling surfaces and forms where the bottom and sides intersect a sharp corner, and not the conventional curve seen in Fig. 3. That steel behaves in a precisely similar manner is known to those furnacemen who have opportunities now and again of seeing ingots broken up that have been upset or otherwise accidentally and completely bled.

The influence exerted by size and shape of ingot moulds on the position and dimensions of the pipe will be discussed later, but it is desirable at this stage to consider a feature exhibited by many ingots cast in straight-sided moulds as distinct from taper moulds used with either the narrow or the wide end up When sufficiently removed from the cooling influence of the closed bottom and the open top of an ingot mould the freezing of any horizontal section of the fluid ingot may be regarded as due to loss of heat through the sides of the mould. When the mould has the same cross-sectional dimensions from top to bottom the crystals growing from the sides in any one plane are as likely to meet in the centre as those growing in any other plane. Now in both commercial stearine wax and in steel a plane of the material may be all but rigid, quite too rigid at the centre to flow downwards, but requiring still to contract over its entire area. The material next the ingot mould is coldest and most rigid, and if the unavoidable contraction cannot pull the flat outer surfaces inwards, the assumed plane must split at the centre where the material, all but set, offers little resistance. The result is a small central cavity with no material above it fluid enough to flow downwards, and the net effect in an ingot of this kind is a number of cavities roughly spherical in shape, lying in the axis of the ingot. For shrinkage or contraction cavities of this kind an increased length or breadth of feeder head is a doubtful remedy, as in actual practice cuch cavities occur always in small crucible ingots cast into straight-sided moulds and fed by means of a hot dozzle.

To these two kinds of cavities, viz., the pipe proper and a continuation of the pipe that exhibits itself as a kind of axial sponginess, which, when elongated, may be regarded as a secondary pipe, we must add also cavities, axial or otherwise, arising from the contraction of the hot solid ingot. Such cavities may occur in ingots independent of their shape, and should perhaps be described as contraction rather than shrinkage cavities.

An ingot which has quite set and is still hot contracts in volume on cooling, but as the outer surface of the ingot is hard and will not yield much, the stress of contraction will be satisfied, wholly or partly, by the formation of internal cracks or cavities in those positions where resistance is least. In a solid ingot there are certain planes of weakness, due to the arrangement of the crystals, which converge from the corners of the mould towards the axis of the ingot. An ingot is therefore easily split along its axis by tensional forces acting at right angles to its length; and it is further induced to yield to such forces by the fact that the ingot is hotter in the centre and weaker also on that account.

This explanation accounts equally well for axial cavities and cracks formed just before or just after complete solidification. As, however, the contraction of the hot solid material takes place continuously in those parts of the ingot already solidified, and does not wait until the entire ingot becomes solid, we may expect to find contraction cavities which were formed whilst the centre of the ingot was still fluid, and in that case they would not of course be formed at the centre.

From the moment that a solid envelope is formed about the liquid the crystals growing from the sides of the mould form planes of weakness where they meet obliquely, and it is along these planes that contraction cavities are located. They are easily seen when a stearine ingot, cast under favourable conditions, is split diagonally along its length. These cavities all converge to the centre of the ingot, and appear to depend on and originate from an axial cavity. That they are not

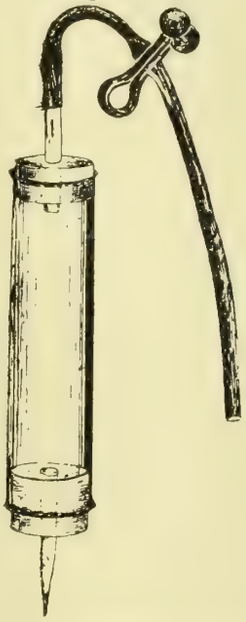


FIG. 4.—ARRANGEMENT FOR CASTING WAX TEST INGOTS.

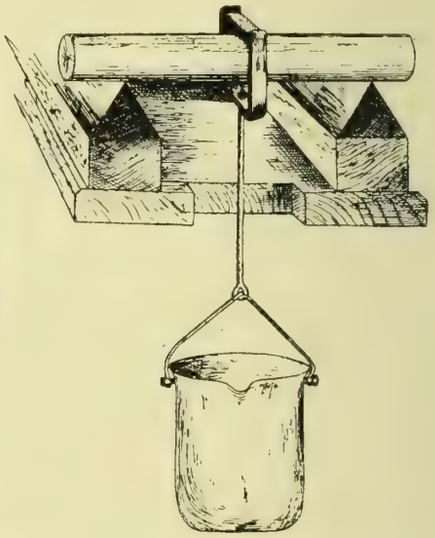


FIG. 5.—ARRANGEMENT FOR TESTING STRENGTH OF WAX INGOTS

developed in that order, but begin to form whilst the centre of the ingot is quite fluid, could be shown by bleeding partly frozen ingots and bisecting the solidified shell diagonally.

There are several reasons why contraction cavities should lie along these planes, extending from the corners to the centre of a square ingot. In the first place the planes are formed by the intersection of surfaces of the ingot which at successive moments were the last to solidify; and about the angle thus formed the contraction stresses are localised with the consequent danger so often exhibited in the hardening of steel tools cut with sharp corners as keyways, &c. Then any absorbed gases liberated at the moment of setting and impurities likely to segregate are also to be found in abnormal amounts along these planes. It needs therefore nothing but a favourable concourse of circumstances to produce large cavities or even extended cracks; and in average cases it needs very little force in addition to the ordinary contraction stresses to cause rupture. But in addition to cavities that are obvious to the naked eye it is not unusual in steel ingots to find cracks running between the crystals at right angles to the surfaces of the ingot mould. These cracks are discoverable by direct microscopic observation.

Cracks may be revealed in large numbers by immersing a disc of steel in a 10 per cent. solution of hydrochloric acid. The acid attacks the metal most vigorously along the edges of any existing cracks, and eventually the crack widens into a

visible cavity. Cavities which originate from segregated areas may also be developed by extended pickling; but there are decisive means of distinguishing one kind from the other, and confusion is not likely to arise if careful observation be made of the scattered distribution of the former compared with the occurrence in groups of the latter

Radial cracks may occur in steel ingots which do not exhibit elongated crystals on a fractured surface. When a disc cut from a large steel ingot weighing, say, 40 or 60 tons, or from a circular billet which has been forged from such an ingot, is polished and etched with a very dilute solution of nitric acid in alcohol, the intercrystalline cracks are located by the evolution from them of small gaseous bubbles. That the gaseous bubbles may escape more easily it is advisable to arrange the disc with the polished face in a vertical position and wash it over by means of a broad camel-hair brush with the etching fluid; small strings of bubbles then run with the solution down the face of the disc from one or two or maybe a score or more cracks. The objectionable features of contraction cracks are emphasized by segregation or slag occlusions, and these as well as the amount of hot work done in the forging determine whether or not the crack will weld up.

If the material in which the cracks appear is not weldable, then it is also not forgable, and will crumble under the hammer. This explains why some alloy steel ingots may not be forged, whereas others of the same composition, but melted and cast under different conditions, forge fairly well. The number and magnitude of the cracks would obviously be increased if the steel had air-hardening properties.

Casting Temperatures.—When a crucible steel ingot breaks with a needle-like fracture (Fig. 1, *c*) it is said to be "scorched," and scorching is said to be due to the molten steel having "had too much fire." A furnaceman does not generally commit himself by saying whether the steel has been for too long a time in the furnace or at too high a temperature. He may not know;* but he does know a scorched ingot can be broken across with remarkable ease, and that he will very likely get into trouble if he makes many such ingots. Scorched ingots are objectionable only on account of their fragility, due to arrangement of the crystals in definite directions, and the extended contraction cavities which may arise. This is, of course, a serious objection, because unless the scorched ingot, after reheating, is very carefully, and, to begin with, very gently forged the weakness between the well-developed crystals will cause cracks to form at the corners of the forged bar. But apart from obvious defects like this, the quality of the steel is neither better nor worse for having shown the scorched appearance in the ingot.

The characteristic appearance of both the inside and outside of "cold cast" ingots are understandable after seeing a stearine ingot cast into a glass mould. First as to the outside. As the wax, per assumption, has already reached its freezing temperature it solidifies immediately on contact with the bottom and sides of the mould. It freezes also over the free upper surface into a crust of crystals, and as more fluid wax is added the liquid level and solid crust rise together, the latter generally increasing in thickness. But the crystal crust has solidified into a piece with the sides of the ingot, and as the fluid wax rises it pushes the crust upwards most effectively where it is least restricted, *i.e.*, in the centre. The crust therefore becomes increasingly convex until, broken by upward pressure of the fluid wax, a new surface is formed. In the act of forming a new surface the fluid wax strikes the glass mould and is frozen before it can fill up the lowest part of the convexity, and hence the surface of the stripped ingot is a series of rings where it has been in contact with the mould, and a series of depressions lying alternately between them where it has not been in contact with the mould.

Pieces of broken crystalline crust are washed into the fluid material, and form independent centres of crystallisation in both stearine and steel. But in steel they may also form blowholes, due to a gas liberation promoted by their oxidised surfaces, and also irregular lines of weakness which may not weld up completely in the subsequent forging. The internal structure of a "cold cast" ingot is unlike that of a hot cast ingot, because in the former case the centres of crystallisation are dispersed throughout the entire ingot instead of being confined to the inner surfaces of the mould or the solid metal envelope already formed from it. The crystals therefore do not grow in planes but in all directions, and form spherical clusters floating in the fluid like seed-pods of a dandelion floating in still air. The clusters of solid crystals are heavier than the fluid steel and tend to sink to the bottom of the mould.

We have said that an ingot freezes by a gradual and uniform thickening of its solid walls in planes approximately parallel to the inner surfaces of the ingot mould. But this statement applies only when the conditions are such that the interior fluid is a perfect liquid. If free crystals form in the liquid independent of the cooling effect of the mould they will rise, as in antimony-lead alloys, if they are lighter, or sink as in stearine and steel, if they are heavier than the mother liquid. In the latter case the base of the ingot will be thicker, at any moment during solidification, than can be accounted for by direct cooling effects in those positions.

The presence of separated crystals in stearine ingots can be demonstrated in two or three ways. One way consists of emptying out the fluid portion either by inverting the ingot or by passing a hot rod through the base of the ingot. By the first-named procedure the crystal groups are disturbed, and by the last-named procedure some of the fluid solidifies in passing through the thick cooler base of the ingot. But in either case the information sought can be easily interpreted apart from these interferences.

The formation of free crystals in the fluid material adds considerably to the mechanical strength of an ingot by interfering with the growth of elongated crystals at right angles to the sides of the ingot mould, *i.e.*, by suppressing the scorched appearance. This is apparent in stearine ingots on attempting to split them diagonally, and particularly in attempting to remove the base pyramid as previously described. It is apparent also in small steel ingots by the greater effort required to top them. In large steel ingots the formation of free crystals is also made apparent by the very marked difference in carbon content between the top and bottom of the ingot—in fact, it is impossible to cast a very large ingot of, say, 40 tons or over from the same ladle and maintain, apart from localised segregation, a uniform amount of carbon throughout its length. The steelmaker has therefore to compromise between two evils, *i.e.*, he may either cast hot and emphasize local segregations, shrinkage cavities, and contraction cracks, or cast cold and widen the difference in composition between the top and bottom of the ingot. The crystals first formed in fluid steel contain, of course, less carbon than the remaining mother liquid, and this explains why the settling of the crystals to the bottom of the ingot widens the variation in composition.

To express in definite figures the influence of varied casting temperature on the mechanical properties of steel would involve an enormous amount of labour and require great experimental skill. It would, for example, not suffice to machine test pieces out of an ingot, because the defects to be looked for would sometimes be in the test piece and at other times not; and even if it were practicable to machine always a test piece containing a typical defect it would be quite impossible to arrange for the defect to occupy the same relative position in every test piece, and therefore the tensile properties of the test pieces would vary amongst themselves without indicating any corresponding variation in the ingots from which they had been prepared.

The least objectionable form of test piece is the ingot itself. But as commercial ingots are not amenable to the requirements of testing methods and machines, and as, further, there is no handy means whereby the casting temperature of steel can be accurately measured, we are obliged to content ourselves with general statements to the effect that the casting temperature of steel may be too high or too low to produce the best results. When it is remembered that the correct, *i.e.*, the best casting, temperature differs from one material to another, and for the same material according to the weight and dimensions of the ingots, to say nothing of foundry castings, there appears to be ample room for the exercise of the art as distinguished from the science of steelmaking.

But in making wax ingots the variable conditions are controllable with that degree of accuracy which yields confirmatory results from duplicated tests, and as the behaviour of stearine wax in so many respects is comparable to the behaviour of steel it may be possible by its aid to confirm the

* Text-books say: "If kept too long in the furnace the steel will teem dead, and the fracture of the ingot will have what is known as a 'scorched look.'" This is misleading.

general statements alluded to in the preceding paragraph, and also, by analogies carefully drawn, to add something to it.

Apparently the least troublesome way of casting a series of ingots from varying temperatures is to melt a large beakerful of stearine and cast one ingot after another as its temperature falls. But the application of this method leads to very erratic results, because, in passing over the colder lip of the beaker, the wax solidifies and, in the worst cases, small pieces of solid wax are carried forward into the ingot. These are comparatively harmless when the temperature of the cast ingot is sufficiently high to remelt them, but otherwise they cause what should be a scorched ingot to appear granular or finely crystalline on its fractured surface.

To avoid this irregularity use may be made of glass tubes, 7in. long by ¾in. diam., which have at each end a well-fitting perforated cork. Pieces of thin glass tubing fit into the corks, the one at the lower end being drawn out to a fairly fine point, and the one at the upper end being provided with a few inches of rubber tubing and a spring clip (see Fig. 4). The lower drawn out end of the glass tubing is kept at the temperature fixed for the ingot next to be cast, so that when immersed in the fluid wax the opening is not stopped up. The molten wax is drawn upwards by suction on the rubber tube until the mould is nearly full. The pinch-cock is then closed; the end of the lower projection is dipped into cold water to solidify the wax and so close the opening; the upper cork, together with the rubber tubing and pinch-cock, are removed, and the mould is allowed to stand quietly in a vertical position until it becomes quite cold. Series of ingots are made successively in this way as the temperature of the melted wax sinks; and it is easy to arrange for the temperature to fall at the rate of, say, 1° C. in 15 minutes, thus permitting duplicate or triplicate ingots to be made at each chosen temperature.

The simple piece of apparatus shown in Fig. 5 may be used to test the strength of the ingots made as described. The ingots rest on supports 4in. apart, and midway between the supports the pan is hung into which mercury is allowed to flow from a graduated burette, or into which small leaden shot is poured until the ingot breaks. The burette is then read off or the weight of shot used is noted in order to arrive at the breaking load in grammes. As the results are merely comparative the net breaking loads on the ¾in. circular ingots used are given in Table I.

TABLE I.

Casting temperature. Degrees C.	Breaking load in grammes.					
	1	2	3	4	5	Average.
80	1,618	—			—	—
75	1,671	—	—		—	—
70	1,551	—			—	—
65	1,220	—	—	—	—	—
64	1,292	1,155	1,208		—	1,218
62	1,048	1,009	—		—	1,029
60	1,224	1,274	1,168			1,222
58	982	1,009	1,088	—	—	1,026
56	1,459	1,155	1,605	1,830	—	1,512
54	2,783	2,995	2,783	3,193	3,127	2,938

	Grammes.
One minute after reaching 54° C.	3,250
Two minutes " " "	3,224
Three " " " "	3,021
Four " " " "	2,995
Five " " " "	3,101
Six " " " "	2,929

The most noticeable feature in this series of results is the great increase in strength between those ingots cast respectively at 56° and 54° C., the latter being almost twice as strong, and this is confirmed by the appearance of the fractures, which show a marked difference within this short range of casting temperature. The ingots cast at 54° C. have a granular or finely crystalline structure, whilst those cast at 56° C. and over show scorch. This observation is quite in line with the behaviour of small steel ingots, both as regards appearance of fractured surfaces and mechanical strength. The increase in strength when the casting temperature reaches 65° C. is also notable and not especially difficult to understand. It is to be expected that, all other conditions being equal, a rise in the casting temperature alone would cause the ingots to become gradually weaker, but a rise in casting temperature disturbs the other conditions, and more especially the rate of cooling, so that an ingot cast with wax at 58° C. into a thin mould might at once have a solid envelope formed around it by the cooling action of the mould; whereas when cast from a higher temperature the heat lost in cooling the mould might depress the temperature of the fluid wax to 58° C. without causing a solid envelope to form around it. The rate of cooling in the two cases would then vary, and the latter would be more or less disposed to form the stronger equiaxial crystals, depending on the thermal conductivity, specific heat, and mass of the ingot mould, and on the relative thermal conductivity of the fluid and solid ingot material. It is therefore likely that at some temperature well above the freezing temperature a wax ingot or a steel casting would become stronger, but the rise in strength would not occur at the same temperature of course except under identical experimental conditions.

(*To be continued.*)

THE METALLURGY OF ZINC.*

BY ERNEST A. SMITH, A.R.S.M., M.INST.M.M.

(*Concluded from page 230.*)

THE electric smelting of complex zinc ores was first attempted by the Cowles Brothers in 1883, who developed the resistance type of furnace originated by Depretz in 1849, in which a core of carbonaceous material in the charge itself carries the current in a horizontal direction. In 1901 C. P. G. De Laval erected the first electric zinc-smelting furnace on a commercial scale and four years later works were erected in Scandinavia to carry out his process. Since that time a considerable amount of attention has been given to electric furnaces for smelting zinc ores. As pointed out by Prof. Gowland, "The chief drawbacks that impede the commercial success of the application of the electric furnace to the smelting of zinc ores are the cost of the current and of the electrodes, the loss of metal, and the difficulty of obtaining a fair proportion of the zinc as metal and not as oxide, which has to be re-treated."

The electric furnace is not intended to replace the retort furnaces in the smelting of zinc ores, but to be used for the treatment of ores not suitable for the distillation process, or possibly as a substitute in localities where fuel is dear but hydro-electric power easily available. Early experimental work by W. R. Ingalls, at McGill University, confirmed the opinion that, if electric smelting is to offer any advantages, the process must be continuous, and all modern furnaces are constructed on this principle. In many of the electric furnaces now in use the energy is applied with great ingenuity and high efficiency is obtained, whilst efforts are made to reduce the electrode consumption to a minimum. The reduction in the electric furnace appears to take place more rapidly than in retort smelting, but the reaction between the carbon and carbon dioxide does not appear to occur to such an extent as in the retort. Hence the electric furnace contains an atmosphere comparatively rich in carbon dioxide, so that a larger amount of fume (blue powder) is formed than when the retort furnace is employed.

Cote and Pierron, Johnson, and others have attempted, with some success, to solve the carbon dioxide problem by such means as passing the gases through columns of incandescent carbon. But while progress has been made, the discovery of some means of avoiding oxidation of the zinc deposits, as formed under the conditions prevailing in electric smelting, is still the problem which metallurgists have to solve in connection with this method.

The continuity of operation in the electric furnace appears to imply discharging the residue as a slag that will run, and there has consequently been a tendency for inventors of electric zinc furnaces to render the charge fusible, so that fluid slags may be tapped as from cupolas. This condition, however, prohibits any great excess of carbonaceous material in the charge, and accounts for the higher percentage of carbon dioxide frequently found in continuously operated furnaces.

Among the various types of electric furnace now in use, those of De Laval, Cote and Pierron, Imbert-Fitzgerald, and Johnson may be mentioned. The first two may be selected as typical; De Laval employs the electric arc, and Cote and Pierron slag resistance, as means for converting electric energy into heat.

* From a paper on "The Development of the Spelter Industry," read before the Institute of Metals, September 20th, 1916.

The De Laval process, carried on at Trollhättan, in Sweden, develops heat by means of the arc, current being generated from water power at prices variously given as from 38s. to 50s. per electrical horse-power-year. The works are equipped for 18,000 h.p. The furnaces are of the resistance type, with one large vertical carbon electrode passing through the roof, the other electrode being a carbon block in the bottom of the furnace. Each furnace has a capacity of about 3 metric tons, and smelts nearly 3 tons of ore in 24 hours. The complex ore is roasted to about 7 to 8 per cent. sulphur, mixed with anthracite or coke and flux and charged through a hopper into a closed "melting" furnace, where most of the zinc and some of the lead are volatilised, and condense chiefly as crude spelter high in lead, and partly as blue powder, which has to be retreated. The other part of the lead is reduced to metal and is tapped out with the slag. It contains a considerable proportion of the silver. Some matte is formed, and this and the slag contain some of the lead, zinc, and silver. The crude leady spelter passes to the refining furnace, where the zinc is distilled, producing, on condensation, spelter of high purity and a further quantity of zinc dust, leaving the balance of lead and silver as base bullion. Two melting furnaces supply one refining furnace. The company owning these Scandinavian works reported recently that its smelting operations have not yet proved commercially profitable; considerable progress has, however, been made, and it is hoped that things will eventually turn out well.

The Cote and Pierron process is carried on, on a small scale, at Pau, in France; experimental work was also carried on in 1914, at Ugine, in Savoy, and Quenean, in Belgium. An important feature of the process is the smelting of blende in the raw state. Whilst simplifying the metallurgy of the process, this method increases the difficulties of operation of the electric furnace. "The process is based on the fact that iron replaces lead in lead sulphide at a comparatively low temperature, and zinc in zinc sulphide when the temperature is increased. It is claimed for the process that by its means zinc and lead can be completely separated. The furnace is circular, with sides and bottom lined with graphite, the top being a low dome of firebrick. A carbon electrode, which can be raised or lowered, passes through an opening in the centre of the top, the other electrode, a cone of graphite, projects from the hearth. The furnace is charged through the roof, and the lead, slag, and iron sulphide are tapped through an aperture in the side. The volatilised zinc passes through an outlet in the upper part of the furnace to the condenser, which consists of a cylindrical shaft-like chamber of firebrick filled with coke or anthracite, and provided with a taphole at its base for the discharge of the condensed zinc."

The charge, consisting of a mixture of blende, iron, and lime, is introduced into the hot furnace, and the first reaction of iron on lead sulphide is effected at a relatively low temperature. The resulting lead is then tapped. The temperature is then raised and the decomposition of the zinc sulphide by the iron brought about. The zinc distils over, is condensed in the condenser, the carbon in which is kept at a red heat, to diminish, as far as possible, the formation of zinc fume. Finally, iron sulphide and the slag are run out.

In America considerable experimental work has been done with Johnson's electric furnace at Hartford, Conn., and it is stated that arrangements have been made to erect a 100-ton commercial plant at Keokuk, Iowa. This is a continuous process, with furnace of the resistance type, in which the charge carries the current. The charge is heated to about 900° C. in a continuous pre-heater before reaching the furnace. To prevent the formation of blue powder, the carbon dioxide formed in the smelting zone is rendered innocuous by passing the gases from the furnace through an electrically heated carbon filter, whereby the carbon dioxide is converted into harmless monoxide.

Electric zinc smelting has now passed the mere experimental stage and become a commercial process. It is not correct, however, to say that it has emerged altogether from the experimental stage, since it is being continually experimented upon by those interested in this method of smelting zinc ores.

Since Parnell took up the question of treating complex lead-zinc ores, at Swansea, in 1881, many wet methods have been suggested and experimented with, but until recently none have met with commercial success, owing to their inability to produce metallic zinc. Unlike most metals zinc cannot be precipitated from its solutions by common metals, and if other precipitants are used, and it is obtained as oxide, this must be mixed with carbon and treated by a distillation process to obtain metallic zinc. More recently hydro-metallurgical processes have been devised in which the zinc, after having been obtained in solution, is precipitated in the metallic state by electrolysis; but while the difficulties which formerly attended the precipitation of electrolytic zinc have so far been overcome as to form the basis of recent methods, the high cost of electric power has operated against the commercial success of most of these.

However, where formerly it did not pay to leach out zinc in the form of sulphate, owing to the limited market for the salt, and the prohibitive cost of converting it into oxide, the growing demand for white pigments, free from lead, has made it possible to avoid the necessity for electrolysis by crystallising the dissolved zinc as sulphate. According to Sulman, "the unit of zinc in crystalline sulphate has a considerably higher market value at present than a unit in the form of oxide for smelting purposes," zinc sulphate now being largely required for the production of "lithopone." Electrolytes of zinc chloride solution are said to be more economical in electric current than solutions of zinc sulphate, the electromotive force necessary for the decomposition of the former being less than for the latter.

The only commercially successful processes in the electrometallurgy of zinc by indirect wet methods appear to be those of Nahnsen, Hoepfner, and Dieffenbach. The Nahnsen process has been employed at Lipine, Silesia, from 1893 till the present day, the electrolyte used being a solution of the double sulphate of zinc and magnesium. The Hoepfner process has been commercially successful in Germany, Austria, and England. A modification of the process is in use at the works of Brunner, Mond, & Co., near Northwich, Cheshire, for the production of a fine zinc which is now made in considerable quantities for the manufacture of brass for cartridge cases and other articles requiring a highly ductile alloy.

The zinc ores are leached with waste calcium chloride in the presence of carbon dioxide; the resulting zinc chloride solution on electrolysis gives a zinc of 99·96 per cent. purity (known as Mond zinc), and chlorine gas, which is used in making bleaching powder. The anodes are of lead or carbon, and the cathodes rotating discs of zinc, partly immersed in the electrolyte. The intensity of the current is 100 amps. for 10·8 sq. ft., with an electromotive force of 3·3 to 3·8 volts. The Hoepfner process is in operation at Duisburg, Germany. Two plants were also erected in 1914 at Kristiania and Balestrand (Norway) for the treatment of Broken Hill flotation concentrates.

The Dieffenbach process is applied to Westphalian iron pyrites containing 8 per cent. of zinc, which is extracted by a chloridising roast of the crushed ore, followed by leaching with plain water. The residue, which is said to contain only 0·5 per cent. zinc, is smelted for iron, whilst the aqueous solution of zinc chloride is electrolysed in double-compartment vats, the anode compartment being completely closed. The liberated chlorine is employed in the manufacture of bleaching powder.

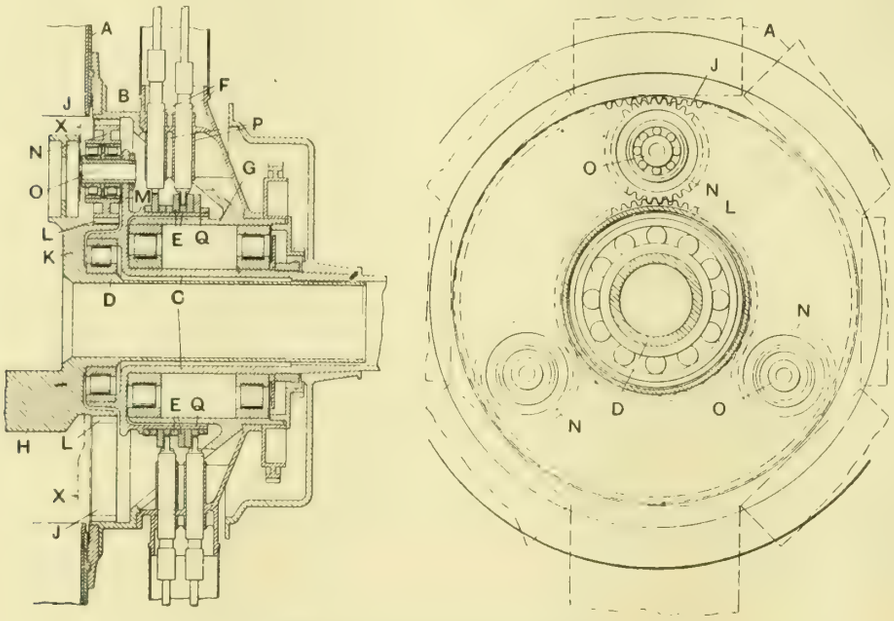
The processes which are being tested in American plants are based on sulphuric acid leaching and subsequent electrolysis of the zinc solution, using lead anodes. The well-known Anaconda Copper Company is now completing a 25-ton plant in which flotation zinc concentrates, after a sulphate roasting, will be leached, with barely sufficient acid to extract the zinc, the resulting liquor being purified by the addition of zinc oxide. This plant when completed will, it is stated, produce some 35,000 tons of fine zinc per annum, and the venture is being followed with considerable interest.

At the Bully Hill mine (Shasta co., Cal.) the zinc sulphate liquor is precipitated with lime, and the precipitate of zinc hydroxide and calcium sulphate is suspended in the electrolyte to neutralise the acid as fast as it is formed. For the same purpose the Reed Zinc Company (Palo Alto, Cal.), in the recovery of zinc from bag-house dust, use a spongy lead anode, which is converted into sulphate. By reversing the current, sulphuric acid and lead are regenerated. At Silverton, B.C., the ore is leached with bisulphate of soda and electrolysis carried out, with the addition of manganese sulphate. The anode becomes coated with manganese dioxide, which is redissolved and used over again. In view of the increasing demand for electrolytic zinc, hydro-metallurgical methods of extraction are receiving renewed attention

ROTARY INTERNAL-COMBUSTION ENGINE.

THE accompanying illustrations show a design of internal-combustion engine of the type in which radially disposed cylinders revolve about the crankshaft, the joint invention of Lieut.-Col. J. S. Ruston, Aisthorpe Hall, Lincoln, and Mr. A. E. L. Chorlton. The engine operates on the six-stroke-cycle and is provided with eight cylinders and a single-throw crankshaft. The cylinders and crankshaft revolve about a common axis, and in opposite directions, gearing being interposed between a fixed member and the cylinders on the one hand and the crankshaft on the other so that the speeds of rotation of the two parts are in a ratio of not less than two to one. The fixed member carries cams from which the valves are operated, the number of the cams and their arrangement being such as to allow firing of the charges in the cylinders, not consecutively, but in cylinders equally spaced apart so as to give power from all the cylinders in successive continuity. Power is taken either off the cylinders or off the crankshaft.

Fig. 1 is a longitudinal section through the crankshaft of the engine, and Fig. 2 is a somewhat diagrammatic section on the line X of Fig. 1 looking in the direction of the arrows. The cylinders A, which are only indicated in chain lines in Fig. 2, are mounted on a casing B. A part G of the casing B is formed as a bearing which rotates on a fixed bearing



ROTARY INTERNAL-COMBUSTION ENGINE.

member C within which is rotatably disposed a crankshaft D having a single-throw crank H. Roller bearings are arranged between the crankshaft and the member C, and between this member and the casing B. Rigidly mounted within the casing B is an internally toothed ring J, and fixed on the crankshaft adjacent to the crank web K is an externally toothed ring L. On the bearing member C is formed a flange M which carries a series of pinions N, each pinion being mounted with roller-bearings on a stud O. There are three pinions N disposed equidistant, as shown in Fig. 2, and these gear with the internally toothed cylinder ring J on the one hand and with the externally toothed crankshaft ring L on the other. The arrangement is such that as the cylinders A together with the part G all rotate in one direction with relation to the fixed member C so will the crankshaft D be caused to rotate in the opposite direction. The gearing is so arranged that the speeds of rotation of the cylinders and crankshaft are in a ratio of two to one. The valve operating cams are arranged as follows: On the part Q are rigidly mounted eight cams E by means of which the valves are operated. This valve operation is effected by valve rods F sliding in sleeves P carried by the cylinder casing. The valves are successively operated by the fixed cams as the cylinders and casing B rotate about the fixed member C. With eight cams suitably formed and disposed on the fixed member the firing of the charges will take place in the cylinders in the following order—1, 4, 7, 2, 5, 8, and so on so as to give power from all the cylinders in successive continuity. The gearing is enclosed within the casing B, and is self-contained.

SCIENTIFIC AND INDUSTRIAL RESEARCH.

REPORT OF THE ADVISORY COUNCIL.

(*Continued from page 226.*)

The Movement towards Trade Association.—It is clear, we think, from these examples that we may expect in growing measure to have the help and sympathy of the manufacturers in the work that lies ahead. It is natural that those who have felt the fires of adversity should be the first to welcome the new movement, but there is growing evidence that many of the most enlightened firms engaged in prosperous industries are alive to the need for long views. The engineering trades have always been able to hold their own, yet they had become convinced before the war that association was necessary, especially in the markets of China and Russia, if they were to compete successfully with Germany. We understand that the British Engineers' Association, like the British Electrical and Allied Manufacturers' Association, intend to include the prosecution of research among their activities. We believe that the so-called price associations are likely in many cases to extend their functions in this way. In other cases special organisation may be necessary. Representatives of over 100 firms engaged in chemical industries, assembled in meeting at Burlington House the other day, resolved "that it is desirable that British firms engaged in the chemical and allied trades should form an association to promote closer co-operation, and to place before the Government the views of the chemical trade generally; to further industrial research, and to facilitate closer co-operation between chemical manufacturers and various universities and technical schools." The association then established has since advertised for a secretary at a salary of £1,000, and evidently intends to act energetically. A Council for organising the British engineering industry, formed in Manchester last year, has recently combined with the British Engineers' Association. This Council appointed a committee to consider Engineering Education and Research, which has put forth a stimulating and comprehensive review of the whole question. It is declared to be one of the functions of such an organisation as theirs "to develop co-operation between engineering firms on the one hand, and universities and technical colleges on the other, so as to establish such 'schools of thought' as exist in the research departments of great continental and American engineering firms, but cannot be fostered in the comparatively small establishments—and smaller research departments—of most British engineering concerns." This sentence strikes a new note, for it bases the need for co-operation upon the comparatively small scale of British commercial enterprises.

The Council have found that many scientific industries are completely without any effective trade associations through which their common manufacturing interests and difficulties can be approached. Broadly speaking, it may be said that the functions of trade associations in this country are not as wide as those of similar associations in Germany. The movements going on around us make it evident, however, that the difficulties of tradition, trade organisation, and national temperament which stand in the way of combination, and which extend far beyond the actual sphere of the Council's activities, must be squarely faced if progress is to be made, and must be dealt with as part of a comprehensive plan.

Beginnings of Research by Trade Associations.—Even those trade associations which exist have hitherto shown but a moderate appreciation of the necessity for research as a means of keeping command of the market. So long as an industry was prosperous it was apt to take short views and feel little enthusiasm for systematic research, especially if the firms it comprised were small, or if the capital engaged had a speculative value on the Stock Exchange. But there are indications of a change of attitude. The Scottish shale oil

manufacturers, who have hitherto been content with an individualistic policy, have, we understand, established a joint research committee, and are making arrangements for a combined research into some of the problems affecting their industry. The Federation of Master Printers have directed the attention of the Council to several substances used in their trade which the war had shown to be supplied solely by enemy countries, and which they urge should be investigated with a view to the creation of an independent source of supply. There are also significant movements among the textile manufacturers of both Lancashire and Yorkshire. We think a good deal of the inertia which British manufacturers have shown towards research may have been due to a realisation, partly instinctive, perhaps, but partly based on experience, that research on the small scale they could afford was at best a doubtful proposition.

Impediments to Industrial Research. Our experience up to the present leads us, indeed, to think that the small scale on which most British industrial firms have been planned is one of the principal impediments in the way of the organisation of research, with a view to the conduct of those long and complicated investigations which are necessary for the solution of the fundamental problems lying at the basis of our staple industries. What, for instance, is the exact nature and constitution of the cotton fibre, or of rubber or of the resins? How does the structure of an alloy depend on its chemical composition and on its mechanical and heat treatment, and what relation is there between its structure and the properties which determine its utility to the engineer? These are questions which none but the greatest of individual firms or a big combination of firms could venture to attack.

The Council are not unaware, however, that there are substantial considerations in the minds of many manufacturers which lead them to hesitate in expending large sums for research of a comprehensive kind. They have complained to us that the recent substitution of the joint stock bank for private banks has hampered enterprise, because the modern bank authorities are not acquainted with the *personnel* and policy of local firms, and are not prepared to finance new undertakings and developments in the same way that the private banks did. We have been told by other manufacturers that the rapid conversion of the businesses in their trade into limited liability companies has thrown the control into the hands of salaried works managers, whose training and experience have been confined to their own industry, and who are therefore apt to resist proposals for improvement.

The Council have also repeatedly been told, when they have urged the necessity for expenditure upon research with a view to improvements and developments, that there is no security that new ventures will not be left, when peace comes, to shift for themselves as best they may in face of the highly-organised competition of our enemies. We do not need to be convinced of the reality of the danger, but we are inclined to doubt the efficacy of any single device for removing it. Organisation can only be fought by counter organisation, and so long as the Englishman treats his business house as his business castle, adding to its original plan here and there as necessity or inclination directs, with his hand against the hand of every other baron in his trade, and no personal interest in the foreign politics of his industry as a whole, it will be as impossible for the State to save him, whether by research or other means, as it would have been for King Stephen to conduct a campaign abroad. In the main the State can only effectively help those who help themselves.

It appears to be incontrovertible, however, that for those industries at least which are essential to the conduct of other important national activities, and which are both scientific in their character and relatively small in bulk, there is very little chance of survival unless special means are taken by the State to safeguard them. We are thinking of those scientific industries—sometimes called key or pivotal or master industries—which can never employ a large proportion of the population, because the bulk of their products needed for the world trade is inconsiderable; and yet without them many other trades would languish or die. Such industries are the magneto industry, the watchmakers' lathe industry, the optical glass industry, the chemical glass and porcelain industries, the fine chemical industry, the dye-stuff, synthetic drug and high-explosive industries. This last group of industries is relatively large. Our annual consumption of dye-stuffs before the war is said to have been about two millions sterling. But if this is compared with the two to three hundred million pounds' worth of textiles produced annually in the United Kingdom, the dye-stuff industry is seen, after all, to fall within our definition. We do not necessarily endorse the view sometimes expressed that all key or pivotal industries should be artificially encouraged, by research grants or otherwise, to establish themselves in this country irrespective altogether of the natural disadvantages under which they might be carried on.

The question is one of balancing the various considerations that arise. If a particular product is essential to the national safety, the case for State action will be stronger than if it is not. If the trade to which the product is a "key" is relatively unimportant, the case will be relatively weak. On this principle the case for watchmakers' lathe-making in this country is weaker than that for dye-stuffs. On the other hand, the argument based on natural disadvantages must not be pressed too hard in dealing with the scientific industries, for these industries undoubtedly show a tendency to arise and flourish in those places in which the processes used in the industry were developed. Moreover, it is undoubtedly a misfortune for the industrial life of a country as a whole if a fair proportion of the most highly-scientific trades is not included among its industries. The general tone and spirit of its manufacture is liable thereby to be lowered, for the best scientific men will not find openings in manufacture, and the status of the industrial man of science will tend to fall. We think, therefore, that it may be desirable for the State to take special pains to encourage those scientific industries which are recognised to be essential to the national well-being, and that accordingly the State may be well advised to assume a greater responsibility for the cost of the necessary research for these industries than would in ordinary cases be admissible.

Other industries, though not so-called "key" industries, may at the moment need special support or encouragement either because they are languishing or because they are struggling to establish themselves for the first time with a reasonable prospect of success, but the question of assisting these will, in normal times, undoubtedly raise considerations of some difficulty.

The Need for a New Outlook.—The Council are also persuaded that if a healthy condition of enquiry is to be fostered in the scientific industries, they must for some time to come expend a good deal of attention and money upon convincing the manufacturing world in general that scientific research is a paying proposition. They believe that the shortest means to this end is an attack upon the pressing problems of manufacture which arise in the course of the ordinary routine—problems which the manufacturers ought, no doubt, to solve by means of their own scientific staffs, but which their present staffs are too small to undertake, often because the firms are too small to bear the necessary cost. It was in this way that the universities of the Middle States of America convinced the farmers that science was useful to agriculture.

Indeed, we recognise fully that unless the generality of British firms can be induced to alter their present attitude we shall have failed profoundly in one of our appointed tasks. In the United States of America there has in certain industries been an earlier realisation than in this country of the large part which the systematic application of science has played in the rapid progress of German trade. Large American undertakings during the last 20 years have set up research laboratories in increasing numbers, and the Council hope that the first of the new series of pamphlets which they intend to issue under the title of "Science and Industry" will show their fellow countrymen something of the progress that America has made, and give some indication of the competition that awaits them in the future. Mr. A. P. M. Fleming, one of the technical staff of the British Westinghouse Company, collected the material for this pamphlet during a recent visit to the States, and by the courtesy of his directors has been enabled to prepare it for publication.

Not less worthy of careful study is the description which is given in the second pamphlet of our series by Dr. C. E. K. Mees, director of research laboratories of the Eastman Kodak Company, Rochester, New York State, of the organisation necessary for successful industrial research. In this paper

Dr. Mees points out that three grades of laboratory are needed by every manufacturer who wishes to get the best results from the application of science to his business. First, he needs the ordinary routine or "works" laboratory for controlling the quality of raw materials, finished products and processes. Next, he should have what Dr. Mees calls an "industrial" laboratory or, as it might perhaps be described, an "efficiency" laboratory, where "improvements in products and in processes tending to lessen cost of production and to introduce new products on the market" are worked out. Valuable as this type of work is, it does not go to the root of things. The results it can give are strictly limited. "Fundamental developments in the whole subject" in which a firm is interested require "something very different from the usual works laboratory. . . . . In every case where the effect of research work has been very marked that work has been directed, not towards the superficial processes of industry, but towards the fundamental and underlying theory of the subject." The function of the third type of laboratory —the true research laboratory is to formulate this underlying theory. Without it Abbe's work on lenses, Abbe's and Schott's work on glasses, or the establishment by a firm in this country of the three alkaloids that go to make up ergot and the synthetising of two of them, could never have been accomplished. This kind of research work involves, Dr. Mees tells us, "a laboratory very different from the usual works laboratory, and also investigators of a different type from those employed in a purely industrial laboratory. It means a large, elaborately equipped, and heavily staffed laboratory, engaged largely on work which for many years will be unremunerative and which, for a considerable time after its foundation, will obtain no results at all which can be applied by the manufacturer." The shortest period in which any considerable results can be expected is five years, while results so considerable as to affect the whole industry "cannot be looked for in less than 10 years' consecutive work."

If, then, in the early stages of the scheme, we are prepared to recommend assistance to certain industries for the solution of some of the pressing problems with which they are for the moment confronted, we do so under no misapprehensions. If a manufacturer has the necessary capital and has once realised the value of research, he needs no encouragement to continue. *L'appetit vient en mangeant.* But in other cases we believe the best procedure will be to demonstrate the value of research to industry by carefully-selected object lessons, and by the periodical issue of the pamphlets, which will contain accounts of what has actually been accomplished and what needs doing in this field. In course of time we may hope to be able to abandon these missionary efforts and leave more time and money available for the big national problems that lie ahead.

American and German Practice.—It must not be supposed that all American industries or firms are as progressive as the Eastman Kodak Company, the General Electric Company, or the National Electric Lamp Association, which purchased a park of over 70 acres in which to build a series of research institutes for the service of the 20 odd factories included in their combine. America is still in the stage of experiment in this matter, and the experiments are worth watching.

Research undertaken exclusively for the benefit of one among a number of competing firms, either by a public institution or at the cost of the State, is indeed always likely to give rise to difficulties. Universities and public research institutes are maintained by endowments and public funds for the common good, and any arrangement which gives exclusive rights or benefits to a single firm as against others in the same industry is not easy to reconcile with the public advantage. Even more true is this, as a general principle, of the use of the rates and taxes for such a purpose. It is often said that other countries, and Germany in particular, have made grants to firms for research, but so far as we can ascertain there is only one authenticated instance of a grant from public funds in Germany to an individual manufacturer for research or any allied purpose. The Prussian Government made a grant of, we believe, £10,000 to the firm of Schott, in Jena, to enable them to work out with Prof. Abbe on a practical scale the researches he had initiated into optical glasses. But Schott was at that time the only firm in Germany which made optical glasses, *i.e.*, it represented the whole industry, and this is a material point. The German Governments, no doubt, frequently assist a whole industry by suitable tariffs, preferential railway and canal rates, and harbour dues; and, most important of all, the German States spend lavishly upon education, and especially upon their universities, their great technical and commercial high schools, and their national research laboratories, such as the Physikalisch-technische Reichsanstalt in Charlottenburg and the Chemische Reichsanstalt at Dahlem. They have not, however, save in the single case referred to, used the taxes, either local or Imperial, to pay for research in the interest of a single firm; nor, so far as we are aware, have their universities and technical high schools ever given exclusive privileges to an individual manufacturer.

The Sphere of the Universities and Technical Colleges.—The question of the part which universities can and should take in the application of science to industry is extremely important, but also extremely difficult. We know that British universities have been criticised for not doing more for the industries, although in certain cases their technological departments have been of great service. We know that difficulties have arisen over the question of academic freedom when a firm has desired to retain a professor and his researches for its own exclusive advantage. (It is this kind of difficulty, among others, that the Mellon Institute of the University of Pittsburg is intended to avoid.) We know that the universities and technical high schools of Germany, Austria, and Switzerland have played a leading *rôle* in the development of scientific industry on the Continent. Yet such an experienced observer as Dr. Mees is strongly of opinion that the fundamental theory of a subject upon which the development and maintenance of industry chiefly depend "cannot possibly be carried on to any large extent in collaboration with a university." And he gives cogent reasons for his belief. What is the explanation of these seeming contradictions? We think it very possible that an enquiry into the actual problems that have been dealt with by the Universities of Yale and Pittsburg would show that they have not been of the fundamental character which Dr. Mees has in mind. He lays stress on the necessity for "continuity of application by the same investigators over long periods with special apparatus and with the development of special methods," and sees in this the chief difficulty in making use of the universities.

German experience, when more closely examined, appears to point in the same direction. The special research institutes recently founded in Leipzig and Berlin with comparatively loose connection with the universities of those cities are intended in part, at least, "to provide for special investigations of a longer and more elaborate kind than those which can be undertaken by university students or teachers."* The fact is, that although the German universities and technical high schools have been able in the past to do much for the industries, because their professors have had little routine work to do in comparison with British standards, the increasing complexity and length of the research necessary for modern scientific manufacture is making it increasingly difficult for the professor or the university laboratory to take a dominating share in the advance. The work of Abbe, in collaboration with the firm of Schott 30 years ago at Jena, epoch-making as it was, fell far short both in time and complication of the 20-year long series of researches that were necessary to make synthetic indigo a marketable product.

In the past, no doubt, the freedom of the university professor to work for a manufacturer was of great importance in building up the industries, but we suspect that in present-day circumstances, unless he is himself a patentee like Nernst, the professor of physical chemistry in the University of Berlin, he is not usually more than a consultant to the firms who are interested in his science. One important function which he has exercised throughout he is never likely to lose so long as he keeps in touch with the needs of the manufacturer, namely, that of training a sufficient number of young men for the service of the industrial laboratories in methods of scientific research—and not only in methods of research. The student must not only be taught how to master the literature of a subject and to attack some fresh point in the line, he must be trained no less in the practical routine uses

* Royal Commission on University Education in London, Final Report, page 30, section 73.

of a laboratory and in the way to do things, such as the making of simple apparatus, for himself.

The universities can and must be the main sources of research in pure science, the discoveries in which lie at the root of all practical and technical applications. Yet universities will not be able to do their fair share of this vital service unless they can attract more students and larger funds. But though some progress has been made in the foundation of universities and the number of professors has largely increased, the endowment of professorships, the one safe means in Huxley's view of endowing research, has not kept pace with the number of foundations. Until our universities are in the position to offer appointments which carry with them real freedom from financial anxiety, it is certain that their teachers will not, because they cannot, take the leading part which they should in the national contributions to knowledge. If the universities can do their full share of the new work in pure science they will do much, but they can do more. They can also with their existing organisation assist smaller firms and less important industries to solve the problems immediately in front of them, and they can, no doubt, attack those fundamental problems of research in applied science which are not too complex or too extended in their nature. The chemical constitution of the stilbene dyes was, for instance, worked out at the University of Leeds; research into the nature and constitution of cellulose fibres has recently been suggested for the School of Technology at Manchester; the de-gumming of silk is being investigated at the Imperial College of Science and Technology; the design of steam nozzles for turbines has been the subject of research both at the Royal Technical College, Glasgow, and at the University of Manchester.

(*To be continued.*)

COMPOUNDING AND SUPERHEATING ON FRENCH RAILROADS.

AN article by L. Baclé, in a recent issue of "Le Génie Civil," discusses the economies of fuel utilisation in France through the use of compounding and superheating on railroads. The saving through the use of compounding and superheating, as compared with the amount consumed in saturated-steam operation is, he states, from 15 to 20 per cent., the average being 17·5 per cent. On January 1st, 1914, there were on the French trunk lines 13,691 locomotives, of which 5,751 were equipped with either compounding or superheating or both of them simultaneously. Locomotives so equipped made in the course of the year runs amounting to a total of about 300 million kilometres (roughly 200 million miles). The coal consumption of modern locomotives on the Midi railway system (one of the most important French railroad companies) amounts to about 15·67 kgs. per kilometre. Locomotives having the same output but working with saturated steam and without compounding would, therefore, under the same conditions of service, consume about 19 kgs., or an excess of about 3·33 kgs. per kilometre. Applying this calculation to the entire system of French trunk lines with their total runs of 300 million kilometres, one gets a saving of about one million metric tons per year. In view of the fact that the greater part of the coal consumed on the French railroads comes from England, the importance of this saving becomes especially great at the present time and with the present scarcity of bottoms.

THE PROPER BLAST FOR AN EFFICIENT AIR FURNACE.

BY HAROLD HEMENWAY.

IN the operation of the air furnace for malleable work it is essential to consider the blast required to maintain the furnace at its highest efficiency. The coal consumption, time of heats, and the cost of firebrick used in the upkeep of the furnace must be considered in trying to obtain perfect combustion from the fuel. It is impossible to establish a rule to govern operations, as furnaces vary in size, the grate area changing in proportion to the size of the melting medium. Almost perfect results can be obtained if operations are well controlled. This is of great importance, since good combustion ensures economies in fuel consumption, and with the proper control of the furnace, greater uniformity of product ensues.

The setting of the bungs in the furnace is of utmost importance, if efficiency in operation is to be attained. The brick used for the bungs are laid up in a box containing a frame conforming to the shape of the angle bungs. When placed on the furnace, the completed bungs are in a straight line with the curved sides facing each other. An arch brick placed between them serves to key them firmly in place. The wind bung is set in a slanting position next to the angle bungs. The blast pipes are placed at approximately the correct angle in six tapered openings in the wind bung. As the pipes extend only part way through the bung, the direction of the top blast is not completely controlled by their position. This causes the blast to be directed against the sides of the bung, from where it is deflected down into the furnace. In most cases this results in burning holes in the furnace lining, and invariably it produces an uneven melting action upon the metal. The unmelted iron must then be worked down into the molten portion, making it necessary to shut off the blast. The furnace is cooled down by this procedure, and much of the value of the fuel is wasted.

These conditions may be improved by directing the top blast at the proper angle as it enters the furnace. This is most easily accomplished by placing a clay pipe inside of the bung, so as to throw the flame down against the bottom lining. In a furnace having a decided slope at the neck, it has been found that when the clay pipe is inclined at an angle of 43°, the blast flame clears the bung and strikes the bottom 30in. from the angle. The pipe is made by placing clay in the opening in the brick in which the blast pipe is set. By making the inside diameter of the clay pipe slightly larger than that of the blast pipe, and by carefully modelling the walls to properly direct the blast, satisfactory results may be obtained. A second set of top-blast openings in the face of the bridge wall at the top are used in this furnace. These openings, which alternate with those in the wind bung, are set at an angle of 26°. This allows the flame to clear the angle bungs and to strike the bottom at a point about 4ft. from the angle.

After the volume of air required to operate the furnace has been carefully determined, it is necessary to proportion the amount between the top blast and the grate blast. In most cases this will give less blast under the fire and will increase the amount of top blast generally used. The reduction of the amount of air entering from under the grate slows down combustion in the firebox, and, with proper firing, allows the gas to generate and enter the furnace, where it mixes with the top blast. If the top-blast pipes are inclined at the proper angle, the blast follows the course of the flame and becomes part of it. As it is directed low in the furnace, it will cut through the pig and sprue without hurdling over it. This will cause the time of the heat to be shortened considerably.

Much has been said in regard to the importance of the radiation of heat from the bungs, but there seems to be some doubt as to the value of this theory. If furnaces were operated on the assumption that the radiated heat is of the greater value, the flame would pass high up into the furnace, and while the metal would be satisfactorily melted, the operation would be extremely slow, as the flame would not sweep down upon the bath. The cost of maintenance of such a furnace would be considerably increased because a high-grade, expensive brick would be required for the bungs. The ordinary type would burn out rapidly if subjected to the heat of a melting unit operated according to the radiation theory.

In a furnace with the bung blast pipes properly set, and with the top and bottom blasts carefully regulated, conditions are ideal for prolonging the life of the bungs. Ordinarily, in such a furnace, the angle bungs withstand from 30 to 60 heats, depending largely upon whether they are broken by iron accidentally thrown against them in charging. The other bungs in the furnace proper have a life of from 50 to 175 heats. The bungs on the waste-heat flue leading into the stack last indefinitely and frequently go through an entire season without showing any effects from the heat.

The use of clay pipes allows the outside pipes to be inclined toward the centre slightly so that the flame and metal will not be thrown against the side walls. This prolongs the life of the brick and is an important factor in economical operation of the furnace. The blast in the bridge, which enters through the second set of pipes, protects the bridge from extreme heat, and prevents it from cracking. The time required for

a 10½-ton heat in this furnace is from 4 to 4½ hours. The metal is 13½in. deep. It is believed that with a wider furnace, in which the depth of the metal could be reduced to about 8in., better results could be obtained. Furnace efficiency seems to be greatest when the blast pipes are directed so as to hold the flame low in the furnace, and when the proper relation between the top and bottom blasts is maintained. Under such conditions one grade of low-priced firebrick may be used for both walls and bungs; also the time of heats will be reduced to a minimum. Almost perfect combustion may be obtained, the losses amounting to less than 5 per cent.—"The Foundry."

BOOKS FOR STUDENTS IN CAPTIVITY.

THE first meeting of the newly-formed committee for the management of the British Prisoners of War Book Scheme, a war charity hitherto carried on by Mr. A. T. Davies, at the offices of the Board of Education, but now being registered under the War Charities Act, 1916, was recently held at Whitehall. A letter was read from the Marquis of Crewe, President of the Board of Education, expressing his appreciation of the work done in the past, and of the invaluable services which the organisation could render to British prisoners of war by giving them the opportunity of developing serious interests in different directions during the hard and dreary months of their detention. His Lordship added, that he trusted the work would become more and more fruitful. The following officers were elected: Chairman, Mr. A. T. Davies (Board of Education); treasurer, Rear-Admiral J. F. Parry, C.B., Hydrographer to the Navy. The appointment of a secretary was held over. A gratifying report was read from the Principal Examiner to the Board of Trade (Marine Department) on the result of the recent examinations held at the camp at Groningen, in Holland. Nineteen candidates presented themselves for examination for the Second Mate and other certificates, and all passed, in a highly creditable manner, a searching examination, a fact which, the Principal Examiner stated, bore eloquent testimony to the value of the opportunities for self-improvement afforded at the camp. As a result further classes are now being formed at Groningen for candidates for certificates of competency in the Mercantile Marine. Evidence is also coming to hand from camps as far distant as Asia Minor of considerable development in the organisation of educational work among the men interned there. From these camps a continuous stream of applications for books for serious study was reported to the committee, who expressed the hope that the public will continue, by offers of suitable books (new or second hand), to support a war charity, the need for which was daily becoming more and more evident, and the machinery of which was being increasingly taken advantage of by the friends and relatives of prisoners in all parts of the British Empire. Further particulars respecting this war charity and its work can be obtained on application to Mr. A. T. Davies, at the Board of Education, Whitehall, London, S.W. All communications should have the words "Prisoners of War" written in the left-hand corner of the envelope.

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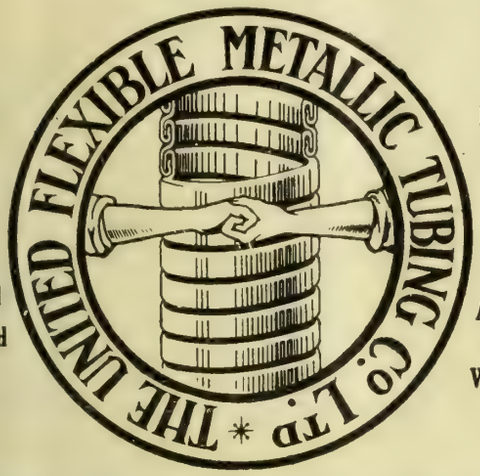

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The Education of Mechanical Engineers.

PROBABLY no subject has been more fully discussed during recent years than the education of mechanical engineers, and yet, notwithstanding all that has been said and written, it is far from having reached finality. Probably it never will be, and it might not be advantageous if it did. The subject is so complex, and can be regarded from so many points of view, that it is impossible to secure uniformity of opinion. This is not to say that discussion is useless or to be deprecated. The more the subject is searched and probed the more are those studying it likely to arrive at agreement on main principles. Teaching authorities whose experience of engineering is derived solely from a technical school or college course are naturally inclined to attach undue importance to the advantages of what may be called purely theoretical or scientific training. On the other hand, a man whose experience has been gained exclusively in the workshop has a tendency to undervalue what he contemptuously dubs as "school-learning" with results that are even more detrimental to progress. This type of individual is, however, happily becoming extinct in engineering circles. He belongs mainly to a past generation and his survivors are a rapidly dwindling minority. More and more it is becoming recognised that engineering is applied science, and that science cannot be efficiently applied to man's needs without an intimate acquaintance with the laws and principles by which it is governed. The question of education from an engineering point of view is how best to co-ordinate the laws and principles of science such as may be taught in the classroom or laboratory with the experience and practice of the workshop, where discipline and responsibility become new and yet important factors in the training of the young engineer. Every army of workers must in the main consist of privates or artisans. Only a small percentage can be junior officers in the shape of leading hands and foremen, and fewer

still can hope to occupy the position of designer, manager, or employer. A small highly-favoured minority may possess the social means or influence which enable them to undergo the continuous preparatory school, college, and shop training, specially designed to qualify them to take officer's rank right away, but any scheme of training for the engineering army must be designed in the main for the great majority who enter as privates, though no scheme in these democratic days can be considered adequate that does not permit and encourage the private to enter the higher ranks, even to the highest, if he has the requisite energy and ability. It is safe to say that whatever schemes are devised, that amongst those who enter engineering, with all the privileges and advantages which social position and influence can give, there will be some that will end by becoming humble workmen, while others will find their very poverty in these privileges an incentive to effort that will carry them to the top of the profession. This is as it should be. Incentive to continuous effort is the only key to real progress. The education of an engineer is not, in its broadest and deepest sense, that which begins at the elementary school and ends at the technological school or university at the age of manhood, but continues throughout his life until he ceases practice. In March, 1914, Principal Garnett, of the Manchester Municipal School of Technology, read a paper before the Manchester Association of Engineers on this subject of engineering education. The paper outlined an elaborate scheme for dealing with boys leaving elementary or private preparatory schools at the age of 12 or 13 up to their becoming finally dovetailed into the profession either as artisans, foremen, draughtsmen, or managers. We felt at the time that the weakness of the scheme was its complexity, but it had the effect of bringing about a very full discussion, and Principal Garnett, in his reply, suggested that the Council of the Association should make public the existing means and facilities afforded by engineering firms for the training of engineers in the Manchester district. Pursuant to this suggestion, the Council appointed a small committee to consider the subject in the light of the paper and resulting discussion and report the result. The committee then appointed has completed its labours, and the report, which has been approved by the Council, has just been issued. It is a valuable document, and its suggestions will, we are sure, meet with the approval of all mechanical engineers who have given the matter serious consideration. The defects of the educational scheme propounded by Dr. Garnett were not only its complexity—which is emphasized by a "flow-diagram" in the report showing its collective and distributive features—but the absence of that persistance and discipline which only the workshop can provide. This is a defect common to most of the schemes of engineering training that have been proposed by educationalists, who are professors rather than engineers, and do not grasp the essential difference in this respect between the college and the workshop. It is only when a boy enters the latter, receiving wages instead of paying fees, that he learns for the first time the full meaning of responsibility and discipline; the value of materials and time; the cost of mistakes, and the necessity of avoiding them. Another serious defect in the scheme was the proposal to start boys on technical courses at the age of 12 to 14. At this early age it is impossible to form a correct idea of what the boy is best suited for, or what is best suited for the boy. The fundamental weakness of British education is the lack of sound elementary training, and the committee in their report set out with this fact well recognised, and further, concentrate their attention on the fact that about 85 per cent. of the apprentices in the engineering trade commence work at the age of 14. It would no doubt be far better for the nation if this age could be raised a couple of years, but under present circumstances it is probably too much to expect so great a change, and therefore any scheme must be based on existing conditions. The main point is that up to the age of 14 nothing in the nature of specialisation should be attempted, and that attention should be concentrated on a sound foundation. Continuity in education is the main point to aim at for boys who enter works at this age, and this, it is suggested, should be secured by blending appropriate education with workshop practice. There are two ways in which this can be done, by part-time day classes or by evening instruction, but we quite agree with the committee's suggestion that up to the age of 17 evening classes should be avoided. Strong lads can attend them without suffering physical deterioration, but, speaking from experience, we know what a hard drain upon strength it is to get up between five and six in a morning, and put in two hours' schooling at night after workshop hours. Day schooling in early youth is far more efficient than night schooling, and though the absence of a boy during two half-days a week at technical classes may cause a little inconvenience in the workshop, it is no more than can be overcome by a little organisation, and would be more than compensated by increased efficiency, while the payment of the fees by the employer would retain his influence over the boy. At the age of 17 evening classes may be attended with much less risk of physical deterioration, and experience shows that with very little encouragement the best boys seek it from self-interest, while the more brilliant could, by aid of the many scholarships and exhibitions available, secure an opportunity for entering a higher technical school, or if sufficiently clever, a university. Such boys would in fact secure the best chances of becoming designers, managers, and eventually employers themselves, although they may have started on the lowest rung of the engineering ladder. The report makes other useful suggestions deserving of brief reference. For instance, much more may be done for the encouragement of bright boys in the works than is done at present by a display of intelligent and generous interest in their welfare. "In large works a man of suitable ability," it is suggested, "might devote all his time to following the scholastic and practical work of the apprentices in answering questions on work in progress, in giving explanations of shop methods, and in inspecting homework, and acting as a judge in granting reward." This may not be feasible in small works, but even there principals might often take more interest in boys than they do. What should be aimed at finally is the production of intelligent, contented workmen and capable, energetic foremen and managers, with equal opportunities for all to advancement, controlled only by personal ability and perseverance.

U.S. Dreadnought to be Propelled by Electricity.—The super-dreadnought "Tennessee," now under construction for the U.S. Navy, is to be equipped for electric propulsion with apparatus built by the Westinghouse Electric and Manufacturing Company, East Pittsburg. Instead of the propellers being mechanically connected to driving engines or steam turbines, two steam turbines developing over 33,000 h.p. will drive electric generators which in turn will furnish current for four 6,700 h.p. motors, each motor coupled to a propeller. By this arrangement the steam turbines may be located in any desired part of the ship, and the propelling machinery is thus better protected from injury than otherwise; and full power is available for reversing, besides great rapidity in manœuvring being possible. Several hundred electric motors will be required for supplying light and power throughout the vessel, and electricity is to be used for cooking, ice-making, refrigerating, and other purposes. In all about 37,500 h.p. of electricity will be needed.

EFFECT OF BLASTFURNACE GASES ON WROUGHT IRON.*

BY DR. J. E. STEAD, F.R.S.

MR. T. H. BYROM, in his paper on "The Carburisation of Iron at Low Temperatures in Blastfurnace Gases" (Journal of the Iron and Steel Institute, 1915, No. II., p. 106), showed that soft steel, when exposed to the action of the gases from blastfurnaces at the Wigan Furnaces, which were employed in the manufacture of ferro-manganese, is substantially converted into carbide of iron, Fe_3C, without the formation of any free carbon in the interior of the mass. The temperature of the gases varied between 600° and 700° C.

Sir Lowthian Bell, previous to 1872, showed that when carbonic oxide is passed over iron oxide at 400° C. and above, reduction of the oxide to the metallic state is more or less complete, and coincidentally the carbonic oxide is reduced to free carbon in the spongy mass.

John Pattinson, previous to 1876, working in conjunction with Mr. Charles Wood, proved that firebricks, used in furnace linings, if they contained free oxides of iron, disintegrated in course of time, due to the same peculiar reaction. The carbonic oxide penetrating the porous bricks, attacked the oxide and deposited carbon, which, exerting enormous pressure, burst the bricks into pieces. Pattinson also recorded the results of an examination of a black powder found in the concrete of a gas flue at the Tees Ironworks. It contained the following:

	Per cent.
Carbon	91·76
Iron	3·54
Phosphorus	0·043
Silica oxygen	1·777
Loss on drying at 212° Fah.	2·880
	100·000

Ratio of iron to carbon ... $\frac{91{\cdot}76}{3{\cdot}54} = \frac{25}{1}$ carbon. iron.

Pieces of cast iron, having all the properties of Cleveland pig iron, were found inside the mass of black deposit. In the incombustible part of the black substance, excluding the oxygen, the elements were found to be associated in the same ratio as they exist in Cleveland pig iron. It was assumed that rusted pieces of Cleveland scrap iron had accidentally got into the concrete, that the carbonic oxide had attacked the rust, and the spongy iron produced had induced the continuous deposition of carbon from the carbon oxide.

The exact reactions which actually occur are far from being clear, and it is doubtful whether they can be dismissed by the formula usually advanced. The question as to whether the lower oxides of iron play any part in the reaction is not clear. It is known that during the carburisation of iron in the cementation process, the carbonic oxide gas is the vehicle of the carbon and that carbon dioxide and iron carbide are the products:—

$$Fe_3 + (CO)n = Fe_3C + (CO_2)n + (CO)n,$$

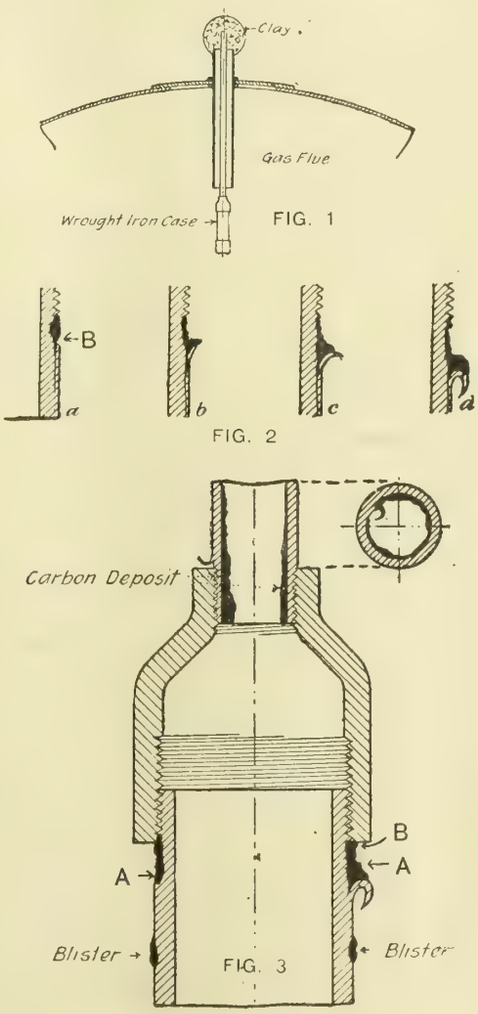
and that it is improbable that oxides of iron play any part as an intermediary.

Much might be written on the alleged chemical and catalytic reactions, but it is not proposed to do this at present, the object being to show that apparently the oxides imprisoned in wrought iron induce carbon precipitation, and the partial disintegration of the iron itself, when such iron is heated in blastfurnace gases rich in carbonic oxide. It has been shown that at 550° C. and above, gases containing about 30 per cent. carbonic oxide and 3 to 4 per cent carbonic acid rapidly carburise iron, but at lower temperatures than 500° C. there is no carburisation.

The object of this note is to describe the effect of blastfurnace gases on wrought iron, at temperatures between 400° and 500° C. The phenomena were observed quite incidentally when experimenting on the magnetic properties of manganese steels with the object of ascertaining the effect of very prolonged heating at relatively low temperatures. Bars of the steel were placed inside of a wrought iron tube or case, and the case with contents was placed in the middle of a gas flue, where the temperature ranged between 400° and 500° C., and was allowed to remain there for nearly two years, but the case and the bars were removed and examined at intervals. Fig. 1 clearly shows the method of suspending the case in the gases.

After exposure for a year, the wrought iron tubes were found to be blistered in many places, and at certain points layers of the iron had been torn away from the places where the screwing terminated and were beginning to curl over in the way illustrated in the sketches (Fig. 2). As one had the opportunity of examining the outside of the case at intervals, the gradual progressive tearing action was followed. From the first it was clear that carbon was being deposited from the gas and was responsible for causing the disruption.

Fig. 2, *a*, *b*, *c*, *d*, show step by step the mechanical effect of the carbon. It is almost certain that that element was continually deposited along the line of cinder, and behaved just as if it were the point of a planing tool. The iron itself was not carburised, as was proved by an analysis which gave only



0·05 per cent. carbon, a fact justifying the conclusion that the temperature had not exceeded about 500° C.

On screwing off the cap to get at the bars, a considerable quantity of fine dense black powder fell out with the bars, and the lower part of the upper tube contained much of the same substance loosely adhering to its sides. In physical appearance the powder resembled lamp-black. All the blisters on the tubes were filled with this black powder, and some had deposited on the inside walls of the thicker tube as well as the walls of the thin tube. Originally these walls, as well as the exterior surfaces, were coated with a thin layer of blue scale, as is usual with all such hot-rolled material. Carbon seems to have deposited over the whole interior surfaces, but none at all on the exterior portions, excepting at the

* Paper read at the autumn meeting of the Iron and Steel Institute, September, 1916.

parts which had been cold distorted at the screwed portions beyond the terminations of the caps.

Fig. 3 represents a section through the wrought-iron case and upper tube and the parts marked A where carbon had deposited. A most remarkable circumstance was noted about the places at A. Parts of the screw-threads had been removed by the disruptive effect of the carbon from the gases. Originally the threads were continuous to the end B, but after two years only the black deposit remained, together with particles of the iron which had been disrupted. A slight coating of black deposit was found on the bars of manganese steel, even on the faces that had been polished. There was not sufficient of the powders to make thorough analyses, but both free iron and magnetic oxide were isolated.

The free iron was determined by finding the amount of copper, given weights of the powders precipitated, and from that the iron was calculated. Each of the powders on treating with dilute sulphuric acid gave off hydrogen gas. The residue, after dissolving out the free iron, contained carbon and a black substance readily attracted by a magnet, and after this was separated the carbonaceous residue contained non-magnetic oxides equivalent to about 20 per cent. of non-magnetic oxide on the original sample. The partial analyses were as follows:—

	Inside the case.	Inside the upper tube.
	Per cent.	Per cent.
Carbon	27·8	72·60
Free iron	10·9	7·90
Non-magnetic oxide	21·0 }	Iron 13·50
Magnetic oxide	26·0 }	
Manganese oxide	1·3	0·25
Silica	2·9	0·90
Total iron	44·4	21·4

The quantity of powder from the upper tube was not sufficient on which to determine the amount of magnetic and other oxides. The larger amount of manganese in the deposit found in the case itself suggests that a portion of it had come from the surfaces of the manganese steel bars.

As the caps were screwed tightly on to the ends of the case, it was supposed the case was quite gas-tight; and if it was, one is forced to the tentative conclusion that carbonic oxide passed through the solid iron. That it is capable of penetrating iron to a depth of about ¼in. at 600° to 650° C. has been proved by previous experiment, but that it should penetrate right through the iron and deposit carbon on the inside walls of the iron tubes at under 500° C., if true, is very remarkable, and further trials are being conducted to confirm or negative these observations.

The explanation offered for the disruptive action on the screwed portion of the tube is that, in the act of making the screw, the enclosed cinder layers and threads were crushed and made very porous to gases, and the CO gas penetrated and burst away the metal above the cinder layers.

On testing the black deposits for carbon by colour, only traces were found in the deposit from the upper tube and 0·21 per cent. in that from the lower tube, but a portion of this may have come from the manganese steels, which contained up to 2 per cent. carbon. Incidentally, it may be remarked that at high temperatures spongy iron reduced from iron ore is rapidly carburised, and it is justifiable to believe that as ore is reduced and descends down the shaft of a blastfurnace it becomes highly carburised before it reaches the melting zone, and not, as is usually assumed, that it remains as spongy iron till it begins to melt. It is more than probable that before the reduced iron is half-way down to the hearth it will have combined with at least 2 per cent. carbon.

In reviewing the result of the observations and experiment given in this note it would appear: (1) That even hard and refractory iron scale and the magnetic cinder enclosed in wrought iron are capable of reacting with carbonic oxide at temperatures between 400° and 500° C. (2) That wrought iron containing free oxides is capable of being partially broken up by the action of carbonic oxide gas on the enclosed oxides or cinder. (3) That under the conditions named even initially non oxidised steel acts on carbonic oxide gas, inducing carbon to be deposited on the surface.

THE USE OF POWDERED COAL IN METALLURGICAL PROCESSES.*

BY C. J. GADD.†

THE process of burning powdered coal is the best method by which to obtain perfect chemical combination of the air and coal, and by which the highest degree of perfection in combustion may be obtained if properly applied. There is no other fuel so responsive to correct application. The greatest precision is required in its control, and it may be said that, so far as the art of burning powdered coal has been developed, it is perhaps in too great a measure dependent upon the human equation.

The essential features necessary for success in the use of this fuel for metallurgical furnaces are: (1) That the coal should have a high volatile content—low in ash. (2) That, after pulverising, the moisture in the fuel should not exceed three-fourths of 1 per cent. (3) That it be pulverised so that at least 95 per cent. will pass through a 100-mesh sieve and over 83 per cent. through a 200 mesh. (4) That the delivery of the coal to the furnace be uniformly controlled, regardless of the quantity required. (5) That it be delivered to the furnace in a thoroughly atomised state, and that combustion be completed while the coal is in suspension. (6) That in the application of this fuel the personal equation be eliminated as far as possible.

The use of powdered coal as a fuel necessitates the installation of an efficient crushing, drying, pulverising, conveying, and distributing equipment, and, in addition, ample storage room for coarse coal. Fig. 1 shows a plan, side elevation in part section, and four cross-sections of a coarse coal storage, drying, pulverising, and conveying equipment. The incoming coal is brought up an inclined plane to the elevated trestle and discharged from cars of the bottom-dump type into the track hopper. A pusher feed located on the bottom of the track hopper controls the flow of coal to the crusher, the crushed coal falling by gravity on to belt conveyor A, which discharges into the shoe of elevator B. Belt conveyor A is fitted with a Merrick weightometer, which affords an accurate check on the tonnage received. The nature of the coal received determines the operation of the crushing rolls. In the case of slack coal, the crusher rolls are set apart and the coal falls by gravity from the pusher feed through the crusher to the belt conveyor A.

The discharge from elevator B is so arranged that it can either be spouted direct to conveyor J, which feeds the coal storage bin over the dryer, or to the revolving screen. All coal placed in storage is spouted from elevator B to the revolving screen, which sizes it to cubes of 1in. and under, the finer coal dropping into the hopper below the screen, thence on to flight conveyor C, which distributes the coal in the storage. The coarser coal is discharged from the screen to the cross flight conveyor D, thence on to the flight conveyor E, from which point it is spouted to cars for use elsewhere. Under the storage pile two concrete reclaiming tunnels are provided, each equipped with a flight conveyor. Chutes equipped with tunnel gates are spaced at proper intervals on each side of these tunnels, through which the coal from the storage pile travels by gravity on to the flight conveyor F or G, and discharges into the reversible flight conveyor H, which in turn discharges into elevator B, from which point it is elevated and spouted to conveyor J, distributing the fuel in the storage bin over the dryer.

A suitable feeding mechanism is located in the bottom of the coal storage bin over the dryer, which feeds the coal at a uniform rate into the upper end of a rotary dryer. The coal passes through the dryer, which removes the moisture, and is then discharged into the dust-proof screw conveyor K, thence into the dust-proof elevator L, thence to the dust-proof screw conveyor M, which distributes the dried coal into the dust-proof storage bin over the pulverisers. From the dust-proof dried-coal storage bin the coal travels by gravity to the feeding mechanism on the pulverising mills. The powdered coal is discharged from the pulverisers into the dust-proof screw con-

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veyor N, from which point it is conveyed to the weighing machine, which automatically registers the weight of fuel pulverised. A by-pass connecting conveyors N and P provides a cut-out for the weighing machine and adjustments, and repairs can be made to this unit without shutting down the system. The weighing machine discharges into the dust-proof screw conveyor P connecting with the distributing system.

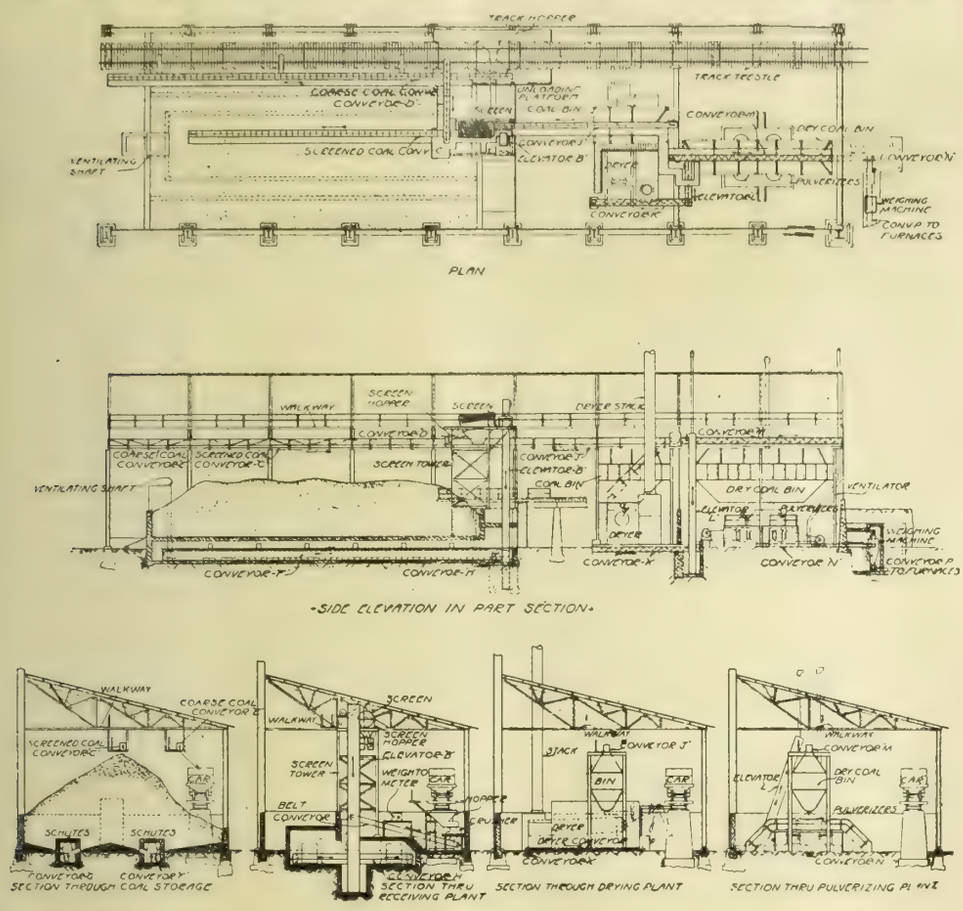


FIG. 1.

Fig. 2 shows a plan and elevation of a powdered-coal distributing system. This equipment furnishes powdered coal to four 50-ton open-hearth furnaces and five double soaking pits. The dust-proof screw conveyor P carries the coal to the dust-proof elevator Q, which discharges into the dust-proof screw conveyors R and T. The powdered coal in conveyor R travels in the direction as indicated by the arrow and feeds the coal storage bins located at furnaces Nos. 3 and 4. Any coal left in this conveyor after passing the coal storage bin at furnace No. 4 is discharged at the end of the line into the dust-proof screw conveyor S below, which returns the surplus coal to the spout X, and thence by gravity to the shoe of elevator Q. With this arrangement there is little possibility of the conveying system being choked through careless operation. The powdered coal fed to conveyor T travels in the direction as indicated by the arrow and feeds the coal storage bins located at furnaces Nos. 2 and 1. The storage bin at the end of the line into which this conveyor discharges eliminates the possibility of stalling the conveyor. In addition to feeding coal to the storage bins at furnaces Nos. 2 and 1, all the coal used by the soaking pits is conveyed over this line. The dust-proof screw conveyor U feeds the powdered coal to the five storage bins located at each of the five double soaking pits. Each storage bin at the open-hearth furnaces and soaking pits is equipped with an automatic weighing machine, recording the weight of coal fed to each furnace, and the coal from these scales is distributed in the storage bins by the dust-proof screw conveyors W.

From the time the coal leaves the dryer to its delivery in the furnace the whole system between these points should be dust-proof and the greatest care should be taken to prevent leakage. This should be guarded against systematically, as leaks, however small, may permit the surrounding air in the room to become impregnated with coal dust to such an extent that a serious explosion may result. Coal, after pulverising, should be handled in bulk. All types of aerial propulsion and transfer in the form of dust clouds should be avoided, for the reason that accidental ignition may at any time wreck the whole system. Screw conveyors and bucket elevators equipped with dust proof casings are best adapted to handling powdered coal in bulk. Screw conveyors of 9in. and 12in. diam. should not exceed 250ft. and 300ft. respectively, if the best results are to be expected. Where transmission lines of greater length are necessary they should be divided.

The storage of powdered coal in large or small quantities for any length of time is not advisable, owing to its tendency to fire, collect moisture, and pack. Powdered coal in storage, containing about three-quarters of 1 per cent. moisture and 1 per cent. sulphur, will invariably fire within six days. If the moisture be increased to over 1 per cent. and the sulphur to 4 or 5 per cent., spontaneous combustion may occur within 24 hours. Probably the temperature at which powdered coal is delivered to the storage bin, and the sulphur content of the coal, influence the rate of spontaneous combustion rather than moisture. Owing to the hygroscopic nature of dried powdered coal, long storage is not desirable.

In its normal state powdered coal is light and fluffy; after 48 hours' standing in storage, however, the physical arrangement of the particles produces a dense packed mass. So dense does the fuel become that one's fingers cannot make an impression even ½in. deep. To meet ideal conditions, powdered coal should be kept in motion. With properly designed machinery and storage bins, having 12 hours' supply placed at each furnace, the coal may be kept in motion and repairs and adjustments made before the supply becomes exhausted.

Fuel.—Low-grade bituminous coals, anthracite, lignites, and even coke breeze in a powdered form, can be burned with good results, certain types of heating furnaces now being operated with such fuels. It should be understood that the first cost of fuel used is not the correct index by which to judge of economy when fuel must be prepared and pulverised. Low-grade bituminous coals, being high in non-combustible

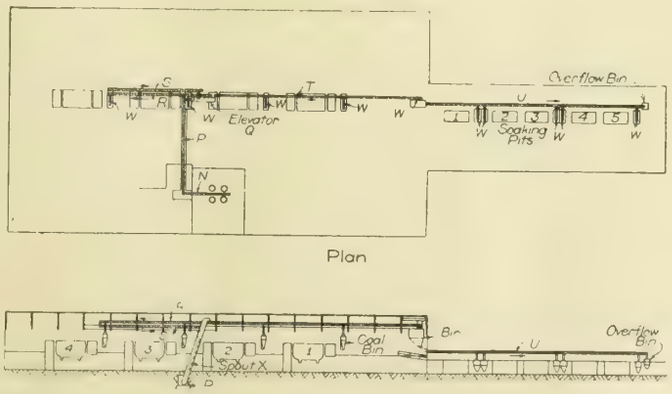


FIG. 2.

content, occasion an inordinately high pulverisation cost, as compared to high-grade bituminous coals. Equally, anthracite coals of highest first cost not only add to the pulverisation cost on account of their hardness, but, although having little non-combustible content, their economy in actual use is not to

be compared to that of the best bituminous coals, because of their high fixed carbon content, resulting in much slower ignition.

One of the disturbing factors in the use of powdered coal is that of the large accumulations of ash deposited within the furnace, only a small proportion escaping through the stack. When using even a good grade of coal, ash will accumulate

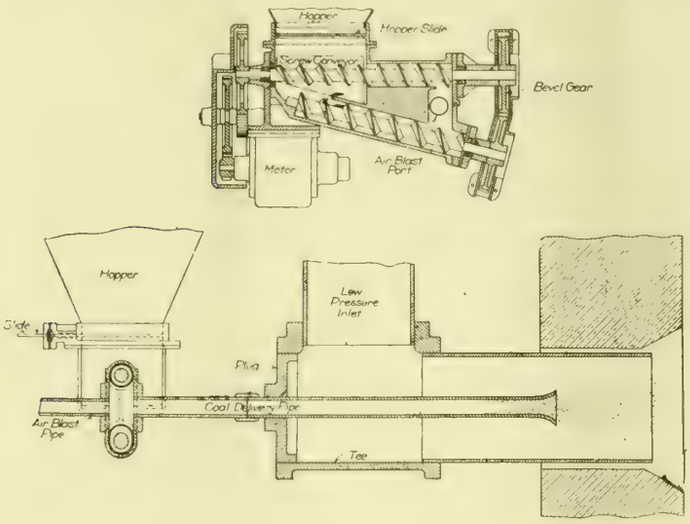


FIG. 3.

rapidly, and therefore fuel of low ash content is always most to be desired.

In obtaining the best economy in any particular case there must be a blending of plant location with the prices of available fuels of varied grades and of the results of tests conducted under operation. Slack coal is preferable to other forms: it costs less, requires less power for pulverising, owing to its fine state, and materially increases the capacity of the pulveriser. While the presence of sulphur in small quantities in powdered coal has no ill effect in heating and annealing furnaces, it should be given careful attention when used in the reduction and refining of metals or ores. Generally speaking, therefore, the fuel available for burning in metallurgical furnaces has a restricted range both as to species and quality. Only the best bituminous coals, high in volatile content and low in both sulphur and ash, are desirable. Coal used in heating and puddling furnaces should closely approximate the following analysis:—

Volatile matter ...	Not under	30·00
Fixed carbon	Not under	50·00
Moisture.....	Not over	1·25
Ash	Not over	9·50
Sulphur	Not over	1·00

In open-hearth furnaces a still better grade is desirable, a suitable analysis being as follows:—

Volatile matter...	Not under	36·00
Fixed carbon.....	Not under	52·00
Moisture.....	Not over	1·25
Ash	Not over	6·00
Sulphur	Not over	1·00

Drying.—The dryer generally used for the purpose of preparing coal before pulverising is of the revolving cylinder type, provided with an external furnace, usually equipped with an automatic stoking device. The fuel consumption of the dryer will vary according to the amount of moisture to be removed. In drying coal containing about $1\frac{1}{4}$ per cent. moisture, to be dried to one-half of 1 per cent. or less, the fuel consumption should not exceed 26lbs per ton. The power consumption for operating the complete drying unit, which includes the power consumed by the coal-feeding mechanism, the dust fan, the stoking device, and in revolving the dryer cylinder for a 10-ton capacity dryer, figures about $1\frac{1}{2}$ kw. hours per ton of dried coal.

In the operation of the dryer care should be taken to avoid overheating, in order not to fire the coal or to drive off part of the volatile content. If the moisture is allowed to exceed three-fourths of 1 per cent., operating troubles result, and these become intensified the higher the percentage of moisture. Moist coal reduces the capacity of screen-type pulverisers, as moist coal will clog the screens. Also, the moisture in the coal governs in a large measure the tendency to pack and to arch in the storage bins, causing an intermittent flow of coal to the feeding device and the consequent loss of the one most essential factor; namely, uniform feed to the furnace.

It is easier to dry coal to $\frac{1}{2}$ per cent. moisture or less than it is to maintain it in this state. This is explained by the fact that the moisture driven off from the coal in the process of drying saturates the hot air contained in the dryer cylinder. In this highly saturated condition the air follows the dried coal through the dust-proof conveying system to the enclosed storage bin. As the coal and air cool, moisture is precipitated and the volume of the air diminished, with the result that more warm saturated air is drawn from the dryer. These conditions, obviously, meet the requirements of a still of fair proportion.

The precipitation of moisture resulting from the cooling process of the coal and air may be almost entirely overcome by placing ventilating shafts on the storage bin and the high points of the conveying system connected with the outside air. Each shaft should be equipped with a ventilator of approved type, and proper provision should be made to collect and deflect any condensation in the ventilating shafts, so as to prevent its return. It is thus evident that in the process of drying, through the medium of heat, a small quantity of the expelled moisture will find its way back in the coal after cooling. For this reason it is good practice to gauge the dryer so that the resultant product leaving the dryer will contain less than one-half of 1 per cent. moisture.

Pulverising.—In order to obtain high efficiency of combustion, powdered coal should be reduced to a fineness so that 95 per cent. will pass a sieve of 100 meshes to the linear inch and so that 83 per cent. will pass a sieve of 200 meshes to the linear inch. Greater degrees of fineness will undoubtedly produce higher efficiency of combustion.

Machinery for pulverising is adapted to two systems of coal-dust burning. In one system the pulveriser has a capacity sufficient for one furnace and delivers the powdered fuel directly into the burner without intermediate storage. In the other system the pulverisers have a large capacity, and one unit will pulverise enough coal to operate several furnaces, the distributing system being so arranged that the powdered coal is conveyed to storage bins, preferably near the furnaces.

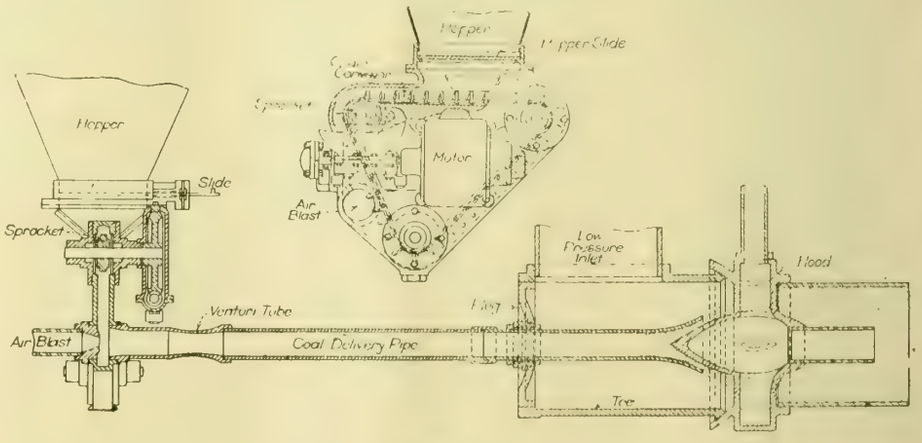


FIG. 4

There are a number of designs of pulverising machines of merit on the market, but only one will be briefly described in this paper. One of the pulverisers largely used is the Fuller-Lehigh mill. The material to be reduced is fed to the feeder hopper of the mill from an overhead bin by gravity. The feeder is mounted on top of the mill and has a range of three speeds; in addition, the feeder hopper is provided with a slide, which permits the operator to increase or decrease the amount of material entering.

The pulverising mechanism consists of four unattached steel balls, which are propelled around the grinding ring by means of pushers attached to the mill shaft. Above the grinding ring and the balls is a fan having two rows of blades,

one above the other. The lower set of fan blades lifts the finished product from the pulverising zone into the chamber above the grinding ring, where it is held in suspension by means of the fan action of the upper row of blades until it is floated out through the screen, which completely encircles the separating chamber. The finished product is discharged through a spout which may be placed at any one of four quarters of the mill. All material discharged from the mill is finished product and requires no subsequent screening. These machines are eminently suited for the production of finely-ground material. They have a high mechanical efficiency and are economical in cost of installation, operation, and maintenance.

In the process of pulverising, a large part of the heat generated is absorbed by the coal and contained air. The temperature which they attain is high enough to expel part of the moisture in the coal, while the air is of a sufficiently high temperature to establish satisfactory saturation. The coal and air cool off in their course through the dust-proof distributing system to the enclosed storage bins, and a similar condition exists as in the case of dried coal, as heretofore referred to. Similar attention must be given to ventilation; otherwise it would be a common occurrence to find water dripping from the bottom of storage bins 10 or 12 hours after filling. The pulverisers, after being shut down, sweat in cooling, and proper ventilation is the only preventive.

The power consumption of the pulveriser will vary according to quantity of output and degree of fineness of the finished product. Pulverising mills of the type described, having a capacity of about 4½ tons per hour, pulverising to a fineness so that 95 per cent. will pass through a 100-mesh sieve and 83 per cent. through a 200-mesh sieve, will consume about 10·5 kw. per hour per ton of product. In a plant having an average output of 200 tons of powdered coal per day the cost is as follows:—

	Per gross ton of coal produced.
Fuel for dryer	$0·030
Repairs, buildings, machinery, and equipment	·200
Labour	·150
Power and light	·215
Supplies	·005
	$0·600

The above figures include all costs, from the receipt of the coal in the cars to its delivery in a powdered state in the furnace. No allowance has been made for overhead and depreciation. Shrinkage in the coal becomes a prominent factor, and must not be lost sight of. It may vary from 150lbs. to 270lbs. per gross ton.

Feeders and Burners.—Powdered-coal feeders are of two kinds—one type consisting of a mechanically-operated screw or flight conveyor having a variable feed, the other type consisting of a siphon, through which the fuel is fed by the medium of compressed air, the feed being regulated by the air pressure. Burners for powdered fuel are operated under either low or high pressure. Low-pressure burners are used with an air blast varying from 2 ozs. to 8 ozs. High-pressure burners are used with compressed air varying from 40lbs. to 100lbs. pressure.

Fig. 3 illustrates a sectional elevation of a mechanically-operated low-pressure feeding apparatus for coal dust, also a sectional view of the feeder taken across the air-blast ports, showing the method of its connection with the burner. By referring to the sectional elevation it will be noted that from the hopper the horizontal conveyor screw delivers a stream of coal in the direction of the arrow mark, which falls as a continuous shower past the air-blast ports, and is picked up by a cross stream of air, which delivers the mixture through the coal-delivery pipe to the burner. The quantity of fuel delivered by the conveyor screw is regulated by varying the speed of rotation, which in this case is obtained through a direct-connected variable speed motor. The amount of fuel taken up by the cross-current of air will vary with the pressure of the air blast, which is controlled by a suitable valve placed in the blast line. Any excess fuel escaping the feeding action of the air blast is automatically returned to the hopper by the lower inclined conveyor screw. The coal-delivery pipe discharges its mixture into the burner, the low-pressure inlet pipe furnishing the necessary additional air for combustion, and the resultant mixture is discharged into the furnace.

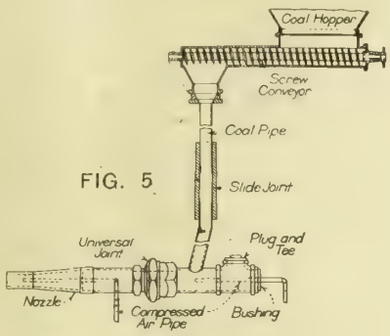


FIG. 5

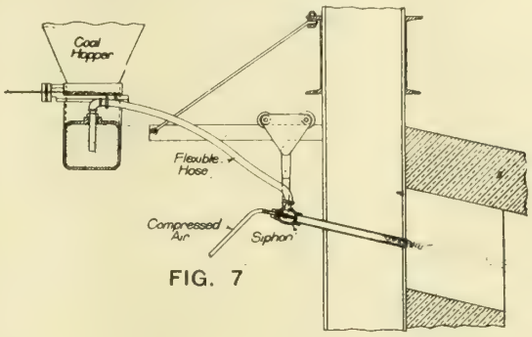


FIG. 7

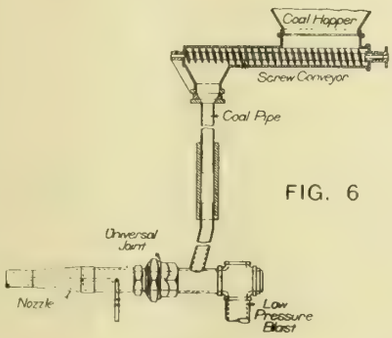


FIG. 6

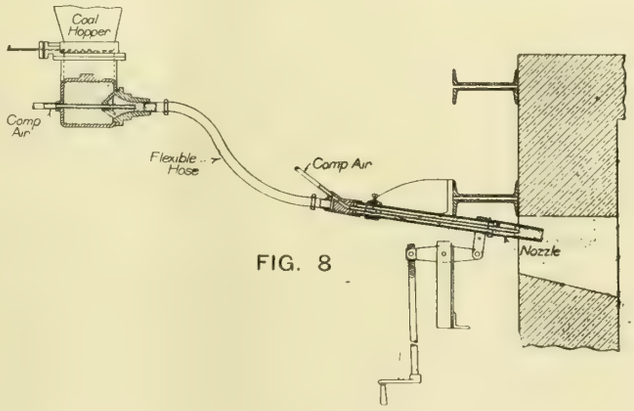


FIG. 8

Fig. 4 shows a sectional elevation of a mechanically-operated low-pressure powdered-coal feeding apparatus, also a sectional view of the feeder taken across the air-blast ports, showing the method of its connection with the burner. By reference to the sectional elevation it will be noted that in this device an endless flight conveyor chain is used for feeding a stream of powdered coal in a continuous shower across the air-blast ports, and the excess fuel escaping the feeding action of the cross-current is automatically returned to the hopper by the endless flight conveyor chain. Variable fuel feed is obtained through a direct-connected variable-speed motor, and the amount of fuel taken up by the cross-current of air will vary with the pressure of the air blast. The air-blast inlet nozzle connecting with one side of the feeder case is reduced, the outlet side being flared, beyond which is a Venturi tube used to induce higher velocity of the mixture leaving the feeder, thereby causing a slight vacuum or pull throughout the case, the mixture continuing through the coal-delivery pipe to the burner. The cone extension on the hood of the burner enters the flared end of the coal-delivery pipe, breaking the solid shaft of coal and air and deflecting it around the inner periphery of the burner pipe. The mixture takes the form of a hollow ring, in the centre of which an auxiliary blast is discharged, giving a very thorough atomisation of the particles as they enter the furnace.

Figs. 3 and 4 serve to illustrate two forms of low-pressure mechanical feeders and burners in commercial use, modifications of which are also in successful operation, all involving the same general principle; namely, a mechanism which will give a uniform and properly proportioned mixture of coal and air, both under variable control, feeding the resultant mixture

in a thoroughly atomised state into the furnace. Feeders and burners of this type are used almost exclusively on the many forms of heating furnaces in the metallurgical arts. This method of burning powdered coal with low velocity of both air and coal produces a short flame, as the fuel combusts almost the instant it leaves the burner, and the heat thus produced is conveyed by the gases from the initial point of firing with less cutting action upon the material being heated and on the brickwork.

Powdered coal will flush, and when once started will run like water. Screw feeding devices should, therefore, be made very long and of a reasonably fine pitch in order to set up enough friction and baffling action to prevent the coal from flushing through the feeding mechanism and causing irregular feed. In the case of the feeding mechanism shown in Fig. 3, long screws would make a cumbersome and expensive device, and efficiency has been sacrificed in this form of feeder for the sake of compactness and cost, as feeders of this design in use at present will invariably flood. They have another very objectionable feature; namely, if the air blast is not turned on and the feeder started up, the screws will jam so hard that the motor is stalled. The arrangement of the inlet and outlet blast through the feeder case sets up a pressure in the feeder, the result being that it not only tends to arch the coal in the bin, but it blows the coal out of the bin or the feeder case, wherever a leak may occur. In addition, under normal running it consumes considerable power to operate.

In Fig. 4 the vertical flights and the conveyor chain have a baffling action which prevents flooding. Under operating conditions it has been proved that the coal will not pack in the feeder should the air blast be cut off. The air-blast nozzle and Venturi tube, producing a suction through the case, have a tendency to prevent arching in the hopper, thus giving a more reliable and uniform feed. In addition, this suction prevents leakages, as there is always an inward pull on the case. This type of feeder takes one-tenth of the power to operate it as compared with the same capacity of screw feeding device shown in Fig. 3.

Fig. 5 shows a sectional elevation of a mechanically-operated high-pressure powdered-coal feeding apparatus. By reference to the drawing it will be noted that in this device a long screw of fine pitch conveys the coal from the hopper and discharges a uniform stream of powdered fuel into the coal pipe. This stream falls by gravity down the coal pipe and is picked up by a cross-jet of compressed air as it enters the burner. The expansion of the compressed air in the larger diameter of the burner thoroughly mixes the coal and air, and this mixture is injected from the burner into the furnace at high velocity by the compressed-air jet at the end of the nozzle. By varying the speed of rotation of the conveyor screw variable fuel feed is obtained.

Fig. 6 illustrates a sectional elevation of a mechanically-operated high-pressure feeding apparatus for powdered coal, which is similar in every respect to that shown on Fig. 5, excepting that low-pressure air of 1lb. pressure is used to pick up the stream of coal delivered to the burner by the feeding device.

Fig. 7 illustrates a siphon-type feeder and burner. By reference to the drawing it will be noted that the coal is siphoned from the hopper into the burner and discharged at high pressure into the furnace.

Fig. 8 illustrates another form of siphon-type feeder and burner. By reference to the drawing it will be noted that a siphon is placed in the coal hopper, discharging a mixture of coal and air into the burner, and the siphon in the nozzle of the burner discharges the mixture at high velocity into the furnace.

Feeders and burners of the high-pressure type produce a long flame through progressive combustion, and can be used only where the form of the furnace and the character of the work demand that an elongated cutting flame be developed in close proximity to the work done. This method of application is adapted to open-hearth furnace practice, and ore nodulising. In the type of feeders and burners described it is interesting to note that the results obtained in the combustion of the fuel are equally good, whether the powdered coal is injected into the furnace from the burner at a velocity of 1,500ft. per minute or of 25,000ft. per minute.

(To be continued.)

THE INTERNATIONAL SYSTEM OF ELECTRIC AND MAGNETIC UNITS.*

BY J. H. DELLINGER.

Two electric units, the international ohm and ampere, have been defined in terms of definite standards by international congresses. These standards are maintained by the national standardising laboratories, and are the basis of all electrical measurements. The units of the various electric and magnetic quantities are derived in practice from these fundamental units by the ordinary equations of electrical theory. Thus a complete and distinct system of electric and magnetic units is in use, based on the international ohm and ampere, the centimetre, and the second. While these international units differ in their derivation from the electrostatic and electromagnetic units, they nevertheless represent very closely the theoretical electromagnetic units. The very slight differences in magnitude between the international and the corresponding electromagnetic units are determined by absolute measurements made from time to time. The electromagnetic units are of much less practical interest than the international units.

One of the reasons why the international system is the most convenient and the most used electrical system is because it is centred around the phenomena of electric current. Electric current is more familiar and of vastly greater practical importance than electrostatic charges or magnetic poles, upon which the other two familiar systems are based. In the international system the magnetic pole is given a subordinate position. Since a free magnetic pole does not exist in Nature and magnetic pole strength does not appear in engineering formulæ, its prominence in the electromagnetic system has not been an advantage of that system. Another fortunate aspect of the international system is the convenience of its dimensional expressions. They are very simple, and directly suggest the ordinary relations of electrical theory and practice. They are, in fact, as helpful in electricity as the usual dimensional expressions in length, mass, and time are in the domain of mechanics. The international electrical system is valuable only in electricity and magnetism, having no utility in mechanics or other parts of physics. It gives dimensions as awkward for the quantities of mechanics as the electromagnetic system gives for electrical quantities, and is, therefore, not of such general application as the systems in which length, mass, and time are fundamental.

The international system furnishes no justification for the use of the word "gauss" as the name for both the unit of induction and the unit of magnetising force. This double usage is an inconvenience in practice.

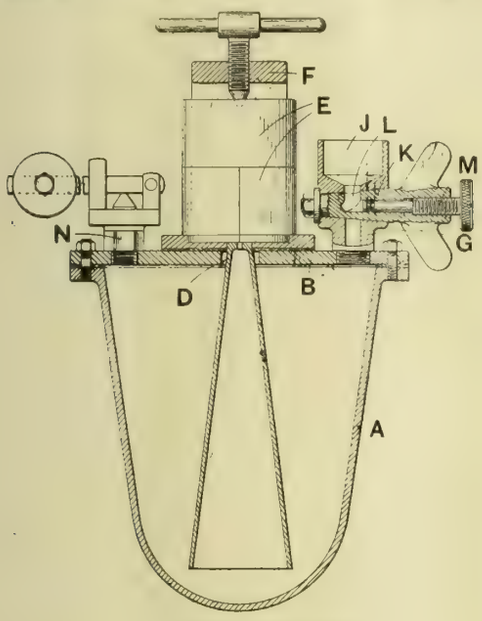
New systems of electric and magnetic units have been proposed from time to time, and some of these are now used to a limited extent in certain books and publications. They all involve the definition of new units of certain quantities in such a way as to redistribute the factor 4π in the equations. An attempt to redistribute the 4π's in an advantageous manner has been called "rationalisation" in the literature of the subject. A careful study has been made to determine whether the advantages of these proposed systems are such as to justify the trouble and confusion incident to a general change of units. No such advantage has been found. Of course, no system eliminates the 4π entirely. All of the proposals except Heaviside's involve changing the unit of permeability by a multiple of 4π. While Heaviside's system leaves permeability unchanged, it makes a drastic change in practically every other unit.

A strong reason against a general change of units for the purpose of rationalisation is the fact that a rationalised system is obtained merely by using the ampere-turn as the unit of magneto-motive force. Upon writing the equations necessary to make this widely used unit fit in with the other units, the system is found to be as good as, or actually superior to, the various proposed systems in every respect. It is interesting that the units which have undergone the evolution of actual use are not wanting in academic appropriateness.

* From Scientific Paper No. 292, issued by the United States Bureau of Standards.

DIE-CASTING APPARATUS.

THE accompanying sectional view shows a construction of apparatus for enabling metals such as aluminium to be die-cast, the invention of Mr. H. H. Wardle, Reliance Foundry, Trafalgar Street, Coventry. The crucible A is provided with a lid B which forms a gas-tight joint and is secured by bolts so as to withstand the required internal pressure. This lid is provided with a manhole for access to the interior, and it carries the delivery pipe D upon which are supported the dies E, the upper of which is held in place by a clamp F. The lid is also provided with a water supply pipe G. For delivering and controlling the water a cup J is utilised, between which and the crucible is a cock K of the measuring type. The cock is formed with a recess L which fills with water when in the position illustrated. When the cock is turned into another position a small quantity of water is delivered at a uniform or variable rate to the interior of the crucible. The size of the



DIE-CASTING APPARATUS.

recess L is known and it may be adjusted by the screw M. The delivery pipe D is centrally arranged, and it is tapered as shown so as to facilitate the return of the unused metal from the dies after casting. By tapering the delivery pipe D, should the metal solidify it will fall back into the crucible. It will be noticed that the dies are carried on the lid B and therefore there is no external pipe. Where an external pipe is used the metal is apt to solidify in the pipe and it is difficult to remove. The lid B is provided with a safety valve N, and also if necessary with a pressure release valve.

British Foundrymen's Association.—The opening meeting of the session of the Lancashire branch of this association will be held on Saturday, October 7th, in the School of Technology, Manchester, at 4 p.m., when an address entitled, "Problems Ahead," will be given by Mr. H. Sherburn, Warrington (branch president). A general discussion upon the subject of "Cupola Practice" will follow.

Mineral Oil Production in Texas in 1915.—H.M. Consul at Galveston reports that in 1915 the production of oil in Texas amounted to 24,825,832 barrels, as compared with 19,990,509 barrels in 1914, an increase of 4,835,323 barrels. The output of the oil wells in Texas in 1915 has been only once exceeded and that was in 1905. In 1915, new oilfields were developed at Thrall in Williamson County and in Palo Pinto and Stephens Counties near Shawn. It is reported, says H.M. Consul, that more prospecting wells are being drilled in the Coastal Counties of Texas than ever before, and that there is ample room with good indications for the discovery of pools of oil as prolific as any that have already been opened. The contract price of oil is double the price paid for the same quality of oil about a year ago, when most of the free oil could be bought at from 50 to 55 cents per barrel, payment in instalments of three, six, and nine months. The prices in January, 1916, averaged from 90 cents to 1 dollar 25 cents per barrel.

SOME PROPERTIES OF INGOTS.*

BY A. W. AND H. BREARLEY.

(*Concluded from page 246.*)

The Taper of Ingot Moulds. If it is assumed that a taper ingot mould with the narrow end upwards is full of fluid metal at a uniform temperature the act of setting may be represented by a series of equidistant lines drawn on a longitudinal section of the mould parallel to its inner surface, as in Fig. 6, A, each line being made shorter than its predecessor to account for the continuous shrinkage. The point at which a pair of these lines meet within the mould may be taken as indicating that in the horizontal plane passing through it the metal has solidified completely. The cavity above the point of intersection is a pipe pure and simple, and may be distinguished as "primary pipe." But there still remains a triangle marked K, which, according to our assumption, contains fluid metal and is hermetically sealed. This fluid in due course will also shrink and freeze and contract, but there is no possibility of the cavities thus formed being fed, and there is formed thus a more or less discontinuous extension of the pipe, which may be called "secondary pipe."

On representing in the same manner the freezing of metal cast into a taper mould with the wide end up, but with shorter steps down because the shrinking fluid is falling from a wider into a narrower part, we arrive at Fig. 6, B. Here also the lines intersect and represent similarly, that the material lying below the point of intersection has become solid. There is also a triangular residue of fluid metal, but in this latter case the triangle is inverted and the metal within it will freeze earliest at the lowest point, any shrinkage being meanwhile fed from above, and leave finally a hollow shrinkage cavity in the axis and at the upper end of the ingot. It is not possible in this kind of ingot to have a secondary pipe.

The assumptions on which Fig. 6 are based take into account neither the speed at which an ingot is cast nor the cooling effect of the air on its upper surface. Ingots are not made by filling moulds at the greatest possible speed, or when they are, the ingots are inferior ones. It may take anything from one-half to fifteen minutes to cast an ingot (depending on its size, the kind of steel from which it is made, and the temperature of the molten steel), and during that time the lower part of the ingot is cooling and the upper part of the ingot mould gets heated before the fluid steel reaches it.

The cooling effect of the air forms a cover of frozen steel of greater or less thickness over the top end of the pipe. In large ingots the thickness of this cover may be several inches; in small ingots it may not persist at all; but in either case the atmospheric cooling thickens also the metal about the upper part of the pipe. If, however, the influence of these variations be added to the hypothetical case represented by Fig. 6 it will not be modified out of all recognition.

Nothing can be done to prevent the shrinking of fluid steel as it passes from the liquid to the solid state; and the only means of providing against the inconvenience of it is to arrange for fluid metal to be kept at a higher level ready and able to flow into what otherwise would be a shrinkage cavity. This means that an ingot must always solidify from the bottom upwards, which it does naturally when cast into a taper mould with the wide end up; or in general terms, the metal in any plane must solidify earlier than the metal in any higher plane if shrinkage cavities are to be avoided.

A fluid ingot cast with the wide end up shortens less rapidly than one cast with the narrow end up, and it is therefore more likely that the upper crust of frozen metal will resist the pressure of the atmosphere when the fluid underneath ceases to support it. This to some not very great extent will help to keep the upper and interior part of the steel fluid; it is more valuable, however, because it may prevent oxidation of the interior of the pipe and thus facilitate its welding when it comes later to be rolled or forged. In one case the pipe may take the form of a long pointed cavity and in another a short cavity with rounded end. Apart from the relative volumes of material thus made unsound, and likely to be scrapped, the former, occurring in ingots cast with the narrow end up, is

* Abstract of paper read at the autumn meeting of the Iron and Steel Institute, September, 1916.

more likely to cause ingots to clink in the reheating furnaces. These are all points of minor importance in themselves, but experience shows that they lead sometimes to grave consequences, and it is therefore worth while to note that in these minor respects the soundness and reliability of the ingot is improved by casting with the wide end up.

The disadvantage of a shrinkage cavity whose surface has been oxidised by exposure to the atmosphere is recognised no matter in what kind of steel it occurs; but it is widely believed that other kinds of shrinkage cavities will weld up without the steel being any the worse. Such a view is not quite in harmony with actual experience, and it may be said that the question is not and cannot be quite settled, as has been inferred, by boring holes into ingots or cogged bars, and then, after sealing hermetically, observing their behaviour on forging.

A hole made with a drill is smooth and perfectly clean. The interior of an unoxidised shrinkage cavity is uneven, and its walls are often lined with small crystallites, which make sharp angles with each other and form very favourable starting places for internal clinks when the ingot is reheated too rashly. On the surface of such cavities one may sometimes find a fine coating of alumina which has been floated there on the decreasing mass of mother liquor, and left high and dry as the last of the fluid falls to a lower level. It appears to be on this

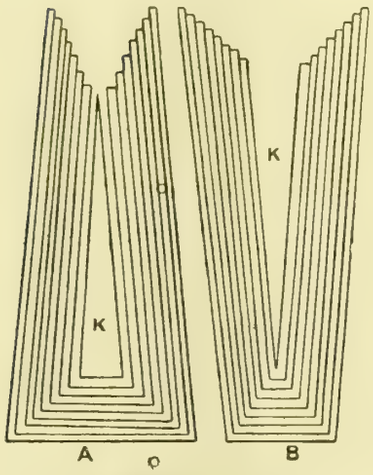


FIG. 6 FREEZING IN TAPER MOULDS.

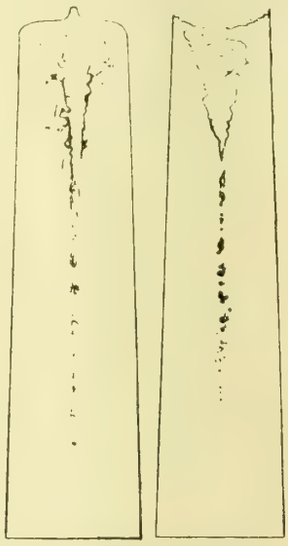


FIG. 7.—SECTIONS OF "BOTTOM" AND "TOP" CAST INGOTS.

account that blisters raised on thin sheets during hot rolling are occasionally found to be coated on their inner surfaces by a layer of alumina of a pale yellow colour. This also has something to do with the lamination of saws and other articles either during stamping or in the subsequent hardening operation.

The central and unoxidised shrinkage cavities lying in straight-sided ingots below the feeder head were at one time during the progress of setting filled with liquid steel which fed the crystallites of purer metal growing from the walls of the cavity. But whilst the fluid metal sank downwards the crystallites remained, and when the ingot becomes a billet or bar that part of it formed by the free-standing crystallites is purer, *i.e.*, contains less carbon and other segregating elements than the surrounding material. This means, of course, that some part of the bar or bars will have a soft centre and cause disappointment if made into chisels or drills, or if made into accurately drilled objects, such as rifle barrels. This kind of defect is most clearly visible to the naked eye in the fracture of steels containing between 0·90 and 1·1 per cent. of carbon, but it can also be detected in lower and higher carbon steels by polishing and etching. The position of a soft centre in a steel bar is the same as that of a hard centre, and the one may occur not far behind the other.

The harder the steel the more important it becomes that the ingot should be free from these axial cavities, and that not only because the danger of clinking is greater and the chances of welding up the cavities are less, but because the harder material at forging or rolling temperatures is less ductile, and under distortion the cavities may actually extend. This observation is notably verified by the behaviour of high-speed steel, and on that account ingots of high-speed steel ought always to be cast in taper moulds with the wide end up and fed by means of a white hot sleeve or dozzle. The neglect of this precaution is one of the contributory causes to which the well-known splitting along their length of high-speed steel tools may be ascribed.

The inverted taper mould is not generally used for ingots whose wider end is less than 4in. across; the reason being that, with the usual taper, the narrower end becomes too small to be struck directly by the molten stream without fear of its having previously impinged on the side of the mould. When a stream of molten steel strikes the side of the mould the ingots are said to be "catched." A catched ingot is regarded as objectionable because it scars the surface of the ingot and may lead either to a lamination, akin to a lap, or a roak on the surface of the bar. On the surface of very hard steel, notably on self-hard steel ingots, a "catch" may lead to deep transverse cracks in the forged bar.

In many cases part of the fluid steel which strikes the side of the ingot mould adheres to it, and is not only solidified but comparatively cold before the steel rising in the mould reaches up to and covers it. The cold strip of steel then adheres and becomes part of the ingot, and may be regarded as an inlaid strip of metal whose inner surface is more or less in contact with the ingot. The strip, however, never melts, and its temperature does not become equal to that part of the ingot in which it lies. As therefore the ingot shortens in length by contraction, the strip, unless it contracted at the same rate, which owing to variation in temperature it does not, will locally resist the ingot's contraction, and small cracks in the ingot may be formed underneath or about the strip. What happens is really a pull on a small scale, but the hardly discernible cracks on the ingot develop into obvious cracks in the bar forged from it. The material immediately beneath a catch is spongy. The sponginess is caused by oxidation of the surfaces of the strip of steel before the metal rising in the ingot mould covers it. The oxide film reacts with the carbon of the fluid metal, as soon as the two come into contact, and small quantities of carbon monoxide or dioxide gases are liberated just as though that part of the ingot mould were rusted.

Sound Ingots.—Sir Robert Hadfield has already extensively studied the question of producing sound steel, and has drawn attention to the importance of obtaining sound ingots. One speaks of sound ingots in a comparative sense. Absolute soundness is never attained, but the imperfections which give rise to no blemish or defect in the intermediate or final stages of manufacture are disregarded; and if they are also equally unobjectionable in the use of the article they are commercially negligible. It may happen, however, that apparent trifles arising in the course of manufacture grow into serious defects or causes of defects in service, and to trace their origin and fix the responsibility becomes a lengthy and delicate matter. If, therefore, an ingot works up into apparently faultless plates and bars and general forgings, it does not follow that the ingot was a sound one, but only that any unsoundness present was of small obvious consequence.

Thousands of tons of ingots known definitely to be unsound in the absolute sense are rolled into girders, plates, rails, and other forms, and appear to yield no worse service on that account. Some others break and involve loss of life and other misfortunes as a set-off to the lower costs of manufacture arising from the use of material which is thought to be good enough, but not so good as it could possibly be made. In producing steel at what is called "the market price," these "insignificant" defects in ingots are made as harmless as possible. In respect to piping and shrinkage cavities this is accomplished by cropping the top end of an ingot, or by avoiding oxidation of the surfaces of the cavities in order to increase their chances of welding up. To a certain extent this latter aim is secured by bottom-casting, but direct attempts to secure its success have been made in other ways, *e.g.*, inverting the partly solidified ingot.

Individual steelmakers are to be found who contend that bottom-cast ingots can be made perfectly sound in the usual mould by using a long trumpet and feeding it with hot metal. This, on the face of it, is highly improbable, however long the trumpet is made, as the steel in some parts of the runner brick

will certainly freeze across, and thus hermetically seal up the ingot before the interior parts of the ingot have solidified. As to volume of shrinkage cavity, there is not a great deal to choose between a bottom cast and top-cast ingot which have been poured at the same rate; the advantage enjoyed by the former is that its cavities are likely to be sealed from atmospheric oxidation.

If the feeding of a bottom-cast ingot through the trumpet be left out of account and we imagine the mould to have been instantly filled with fluid metal, then it does not matter whether the filling took place from the top or the bottom. The position and size of the shrinkage cavity would be the same in either case, except that with a closed top mould a thicker upper crust would form and there would be small chances of bridges forming beneath it. The first advantage then of bottom-cast ingots is that shrinkage cavities are more likely to be clean and weld up.

The metal rises in the mould more slowly on bottom-casting both on account of the mass of grouped ingots and also because each mould is filled against the pressure of the column of metal in it. The steel freezes through contact with the mould whilst it is being cast, and at the end of the casting period the solid shell would be thicker, if bled, than the shell of a top-cast ingot of the same size; this is all to the good so far as volume of shrinkage is concerned. Moreover, the ingot is fed under pressure by metal from the trumpet so long as the runner bricks remain open, and this again lessens the volume of shrinkage cavity.

As steel rises slowly in the mould, beyond the disturbing influence of the incoming stream, it heats up the sides of the mould and becomes itself colder, so that when the mould is full and the trumpet pressure can avail nothing, the freezing of the ingot is completed downwards from the narrower top end containing colder metal to the wider bottom end containing hotter metal. The ingot therefore may have two infected areas; one at the top occupied by a pipe, and one in the lower third of the ingot occupied by spongy metal. Sections of top and bottom-cast ingot (12in. square) are reproduced in Fig. 7.

The slower rate at which grouped ingots are cast is an advantage so long as the rate of casting is not too slow. Under normal circumstances the rate will be determined by the number of moulds to be filled through one runner, their cross-sectional area, the height of the trumpet, the amount of metal coming through the ladle nozzle, and the area of the passages in the runner bricks. To these must be added the temperature of the steel and its freezing point.

The clean skin expected on ingots cast from the bottom is not always realised. When cast too slowly the ingots are folded on the surface, and when steel is run down the trumpet too quickly to begin with it rises like a fountain through the bottom and splashes the sides of the moulds. When cast at average speed the molten metal runs rather sluggishly to begin with along the cold runner bricks, and when first sighted, at the bottom of the mould, appears as a nodule of pasty metal. By pressure from the increasing head of fluid in the trumpet pipe the nodule is forced out of the hole and the metal enters more or less quietly.

As the area of the opening in the trumpet pipe is less than that of the combined openings in the runner bricks, the steel having once properly entered the moulds feeds quietly into them. Later, however, a head of metal must form in the trumpet to overcome the fluid pressure inside the moulds and break through any crust forming on the upper surface of the ingots. The heavy fluid thus pressed through a circular opening is expected to travel up the axis of the ingot mould and diffuse itself into the surrounding metal as it rises; there is reason, however, to believe that it often acts otherwise. The thickness of the runner brick, where the vertical opening is made, is approximately half an inch. Even if this opening were made and set mathematically true the stream would not make headway vertically through the moving mass of metal; it would be diverted first to one side and then the other by uncontrollable incidents.

But runner bricks are made and laid in the casting plate by human agencies; and sometimes the opening is sloped and sometimes it is chipped or has a fash on one side. Either incident will cause the metal delivered under pressure to be diverted from the vertical, and that part of the mould in direct line with the sloped opening in the runner bricks will be washed by the incoming steel, and may have a cavity melted out of it. This is represented diagrammatically in Fig. 8.

The mould is attacked in this manner at varying heights, sometimes as much as 16in. from its base. If the opening lies centrally under the mould the steelmaker may hesitate to believe that the cavity when disclosed can have arisen from any defect in the casting arrangement. It is much easier for him to think that the mould as delivered by the ironfounder contained such a defect more or less consciously concealed, and the view seems to be justified by the fact that troubles of this kind arise more frequently in new than in old moulds. The reason, however, for this apparent justification, apart from the fact that new moulds are more carefully scrutinised, lies in a difference between new and old moulds, the inner surfaces of the latter being protected to some extent by the deposit of oxidised metal which thickens on them by use.

Deflection of hot metal to one side of the mould favours the formation of cracked ingots. This remark ought to be decorated like a recurring decimal when applied to the casting of hard steel ingots. If the runner brick does not open in the axis of the mould the incoming streams cannot possibly form an ingot whose temperature is uniform, and the chances of the surface of the mould being cut are increased. If the mould rests cornerwise on the runner brick, so that the stream of metal before entering the mould runs along a diagonal of the

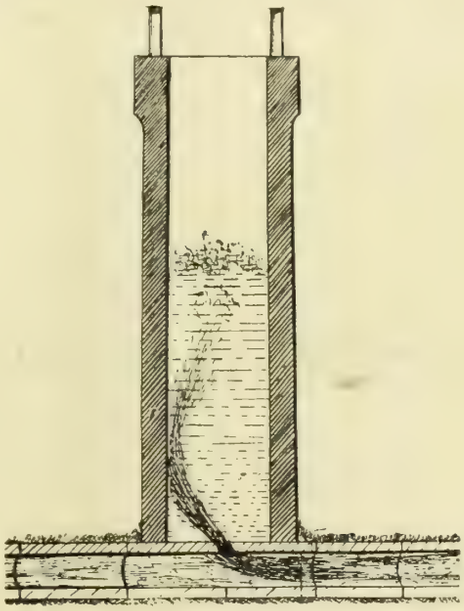


FIG. 8.—EFFECT OF SLOPED OPENING IN RUNNER BRICK.

ingot, which owing to bad design of the bottom plate or considerations of space may occur, then the corner of the ingot to which the moving stream is directed is very apt to crack; and if not cracked on that corner the ingot will certainly not be cracked on any other. In such cases cracks are to be found only in the lower parts of the ingot; higher up the force of the stream is dissipated as the head of metal increases.

The most advantageous arrangement, within the authors' experience, for casting groups of ingots is a solid-bottom mould having a central hole provided with a small taper fireclay sleeve as shown in Fig. 9. This arrangement ensures the formation and feeding of the ingot by a stream of fluid steel entering on and passing up the axis of the mould. The fireclay sleeve is also long enough to give direction to the incoming fluid, and both damaged ingot moulds and longitudinal cracks in ingots are practically eliminated. When cast in this manner the mould must necessarily stand with the wide end uppermost.

If we assume a mould to be full of fluid steel at a uniform temperature, then the solid ingot could be sound only if it had been cast with its wide end uppermost. But in all top-cast ingots the fluid occupying the lower part of the mould is colder at the moment casting is finished than is the metal occupying the upper part of the mould, and this to a certain extent depending on the dimensions of the ingot and the speed of casting, is favourable to sound ingots independent of the

direction of taper of the mould. Also the quantitative effect of a taper of, say, 1in. to the foot is not the same on the freezing of a large as a small ingot. In a small crucible mould, for example, the area of transverse sections a foot apart might be in the proportion of 4^2 to 5^2 and in a larger ingot in the proportion of 20^2 to 21^2; but in the latter case the speed of casting would naturally be more favourable to the production of sound ingots than in the former if both were top-cast. For these and similar reasons it is not permissible to apply rigidly the results of observations made on small ingots with ample taper to much larger ingots cast with so small a taper

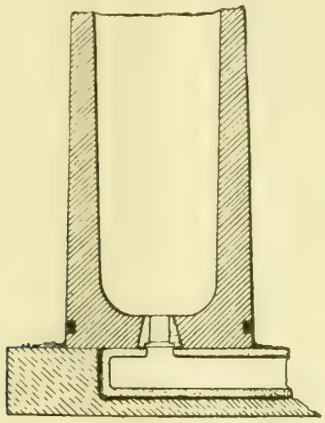


FIG. 6. DETAIL OF MOULD FOR BOTTOM CASTING.

that they can be stripped only with a machine. Much variation of opinion and a great deal of the recent controversy about sound ingots arise from neglect of this important difference. The difference, however, is one of detail, not one of principle, and the inverted mould should be adopted as the safest means of securing freezing of the ingot from the bottom upwards whatever may be the size of the ingot.

As a means of feeding the unavoidable shrinkage cavities in the upper part of an ingot, the simplest and most effective device is the white-hot fireclay head or dozzle used by the crucible steel maker. No feeder-head and no system of producing really sound ingots involves so small a percentage of waste. But the device has not been applied to very large ingots, nor to groups of ingots cast through the bottom from a common runner. A refractory head in the form of a brick lining in the upper part of the mould or, more economically in some cases, as a superimposed piece, as indicated in Fig. 10, can be operated with a discard of 10 to 15 per cent. of unsound and segregated material.

Apart from shrinkage cavities the inverted mould is advantageous in another important respect. When steel is cast on the cold side, as certain kinds should be to facilitate cogging in the forge or mill without cracking, there forms on the upper surface of the fluid steel a crust of crystals which, as previously explained, may be broken and thrown back on to the sides of the mould, or pieces thereof may be washed into the ingot and form blowholes and other centres of weakness. In the ordinary form of mould this frozen surface is being pushed, as the steel rises, into a constantly decreasing area, and it must ultimately break up or allow the steel to flow over it. In the inverted mould, on the other hand, the frozen crust is rising always into a larger area, which keeps its edges free and permits it to grow without becoming thicker and stronger; consequently there is less danger of the crust being broken, and it is possible to produce groups of ingots at a lower casting temperature.

The principles of ingot-making already briefly described are applied in the following pages to a few of the problems arising in ordinary works practice. One of the most difficult of these is segregation and the occurrence of ghost lines in large ingots. If an ingot can be made to consist entirely of long narrow crystals, the segregates are crowded into the centre and towards the top of the ingot. But a large ingot could not be made to consist entirely of such crystals, and somewhere between the outside and centre of a cross-section there is a more or less clearly defined boundary between crystals growing inwards from the outer shell of solid steel, owing to heat conduction, and crystals deposited from the mother liquor whose temperature has fallen to freezing point. This boundary line can often be seen on a well-made sulphur print of common steel. The chill* crystals, which extend inwards from the already solidified shell, form a compact mass. They grow into close contact with each other, pressing the less pure and more fluid material from between their faces and confining it within a receptacle which becomes continuously narrowed. When the temperature of the fluid metal within this receptacle falls to freezing point then "free" metallic crystals form and sink towards the bottom or adhere to the inner surface of the solid walls; and such crystals lie loosely together like thistledown and allow the liquid metal to pass between them.

Talbot has shown, and Neu also at an earlier date, that when the sides of a partially solidified ingot are squeezed together to form a rough bloom, the cross-section of such a bloom shows purer material in the centre and outside than on a median area. The area which is thus found to be occupied by the segregate corresponds to the boundary between the "chill" crystals and the "free" crystals; or more correctly, it should be said that the outer edge of the segregated area cannot lie nearer the face of the ingot than the said boundary line, the reason being that the fluid squeezed from the interior can penetrate the solidified wall only until it reaches the more compact chill crystals. The purer interior of such blooms consists of the free crystals already formed in the fluid ingot metal and suspended therein or attached to the walls. If, therefore, it were thought desirable to move the segregates in a Talbot ingot towards the centre, it could be done by increasing the chilling effect of the mould and raising the casting temperature, *i.e.*, by increasing the thickness of the solid shell before the fluid it contained had reached a temperature at which crystals began to form freely within it.

By reasoning along similar lines we observe that in very large ingots (such, for example, as are used in making gun tubes) the wall of compact crystals starting from the interior of the mould drives before it, as it thickens, a fluid envelope of impure metal which diffuses readily with the hotter metal nearer the centre, as long as both remain quite liquid. When this interior liquid reaches the upper limit of its freezing temperature the more flocculent kind of crystal begins to adhere to the compact walls, and thus restrains somewhat the free movement of the liquid segregate which at that moment occupies the same position. Unless we are prepared to assume

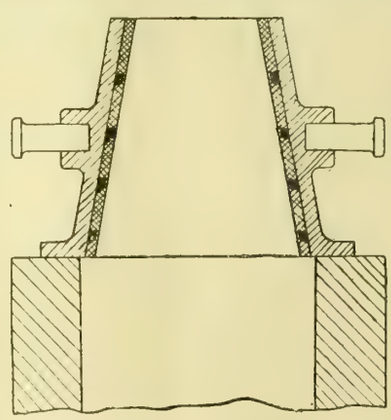


FIG. 10. SUPERIMPOSED FEEDER-HEAD.

a somewhat violent movement of the interior liquid it must happen that the segregated fluid becomes imprisoned and solidified where the two kinds of crystals meet, and as a matter of fact it is from that position inwards that ghosts are found. As a natural sequence one would expect to find the lower part of an ingot, which receives most of the deposited free crystals, to be either altogether or relatively free from ghosts. Also it might be predicted that a line drawn on a longitudinal section parallel to the side of an ingot would cut simultaneously the outer ends of a number of ghost lines.

The explanation given may be confirmed both deductively and by actual observation, but before applying these methods it should be said that the maker of gun tubes first trepans a

* For the sake of brevity those crystals which form at the inner surface of the mould and grow into the liquid steel are called "chill" crystals; and those which form unattached in the cooler fluid and tend to fall on to the bottom or sides of the solid shell are called "free" crystals.

core from the centre of the ingot or from the centre of a large billet made from the ingot. He does not care very much whether the discarded core contains ghosts or not, but it is very important commercially to have no ghosts, or as few as possible, on that part of the ingot which will lie ultimately near the bore of the gun.

(1) In a large ingot cast in a loam mould the ghosts were found to be distributed almost to its edge, and it was not possible from any part of the tube to secure test pieces which would pass inspection. This condition arose obviously from the fact that circumstances were unfavourable to the formation of chill crystals.

(2) As the result of extensive experiment it has been affirmed that much better results are obtained, *i.e.*, there is less trouble with transverse test pieces cut from a gun forging, when the casting temperature is high. This arises from the fact that a high casting temperature is favourable to the growth of chill crystals; but it may arise also because non-metallic impurities, not strictly due to segregation, have a better chance of escaping to the centre and top of the ingot when the casting temperature is high. A portion at least of such impurities may be eliminated in the furnace by careful working.

(3) Other makers of large ingots have been known to affirm that cracks on the corners of such ingots (generally due to high casting temperature) may be taken as a sure sign that the ingot is a good one, *i.e.*, good in respect to freedom from ghosts outside the trepanned core. The effects of high casting temperature in the direction indicated may be admitted, but the remedy is a desperate one, and it may well be asked whether it were not better "to bear the ills we have than fly to those we know not of." If we bear in mind the difficulty of controlling casting temperatures these remarks will suggest, without further comment, why gun ingots made under apparently identical conditions are diversely satisfactory.

The net effect of a high cast temperature is harmful, and it is doubtful whether an exception should be made of gun ingots. It increases the amount of total shrinkage; it increases the number of contraction cavities and intercrystalline cracks; it adds to the weakness of the ingot along planes which lie between the corners and centre of the ingot, and it heightens the danger of clinking in the reheating furnace.

The assumption that an ingot is a homogeneous piece of metal, apart from piping or segregation, is not supported by observation. Take, for example, the well-worn statement that the extension of a round bar of hot steel by a method which includes the revolution of the bar on its own axis will cause the centre of the bar to become hollow. There certainly is a tendency at all times for the bar to split, and it will no doubt actually do so if the working is sufficiently drastic and prolonged, because the simultaneous revolution and elongation of the bar produces a transverse shearing moment through its centre. But whether it will occur or not in an operation carried out always in the same way depends on the properties of the steel, and experience shows that it occurs invariably with some bars but not with others made from the same ingot.

Use has been made of a method which secures the simultaneous revolving and extension of bars under well-defined conditions as a means of comparing the strength of the central axis of ingots cast under different conditions. The ingots were rolled into bars, and these were cut into lengths for testing purposes. From the usual form of ingot only those bars corresponding to the lower third would stand the test without splitting. When cast into an inverted mould about three-fourths of the ingot would produce bars capable of withstanding the test: but if cast very hot even the inverted ingot would not make satisfactory bars.

Some tests were made on bars prepared as follows: The ingot was cogged into a slab, this was sawn longitudinally down the centre, and each half was rolled into test bars. In these tests the axis of the bar would not correspond either with the axis of the ingot or any plane of weakness existing in the ingot, and it is notable that out of 300 tests not a single piece disclosed a split centre.

It is not so easy to make quantitative tests across the planes of weakness originating at the corners of ingots, and the steelmaker is well pleased if he can avoid any obvious defects arising from them. Their presence, however, should not be neglected by the steelmaker nor ignored by the inspecting engineer. They are unavoidably present in greater or less degree, depending on the shape of the mould and the manner in which the steel is poured into it, and more especially on the temperature of the steel. Defects arising from the said planes of weakness are well known; they appear, for example, in the tyre blanks during the beeking operation or earlier.

Owing to the higher coefficient of shrinkage of stearine as compared with steel, and its smaller resistance to tensile stresses, it is possible to exaggerate the defects likely to occur in steel ingots. Stearine can be used also to illustrate the general principles of segregation, and to demonstrate some of the causes of spongy and blown ingots, while its value for teaching purposes can hardly be over estimated.

PROPOSED DEPARTMENT OF MINERALS AND METALS.

The following letter has been addressed to Sir William S. M'Cormick, chairman of the Advisory Council for Scientific and Industrial Research:—

Sir, On behalf and by authority of the Councils of the following institutions:—

The Iron and Steel Institute (Incorporated by Royal Charter as representing the iron and steel industries);

The Institute of Metals (Incorporated as representing the users and manufacturers of non-ferrous metals and alloys);

The Institution of Mining Engineers (Incorporated by Royal Charter as representing coal and iron ore mining and allied industries); and

The Institution of Mining and Metallurgy (Incorporated by Royal Charter as representing the mining of minerals other than coal and iron ores and the production of metals other than iron and steel):

We, the undersigned, have the honour to submit the following considerations and recommendations in the hope that through the intervention of the Committee of the Privy Council for Scientific and Industrial Research, measures may be taken to provide the necessary machinery for the protection and advancement of the economic welfare of the mineral and metal industries of the Empire.

The absence of effective co-ordination of the organisations of these vital industries has been demonstrated and brought into prominence by the war, in many directions. The grave results to the national interests are generally admitted.

There are highly-organised Geological Surveys and Departments of Mines in nearly all foreign countries, and their influence in the development of mineral resources is a factor of the first importance. There are similar well-organised departments in some of the British Dominions, but there is no connecting link or central "clearing-house" in the Metropolis of the Empire to co-ordinate information on its mineral resources, to stimulate their development, and to safeguard Imperial interests.

Various Departments of the Home Government, such as the Geological Surveys and Museum of Practical Geology, the Board of Trade, the Home Office, the Imperial Institute, and, since the outbreak of the present war, the Foreign Office, the Admiralty, the War Office, and the Ministry of Munitions, have all been concerned with the collection of information bearing on the sources of supply of minerals and the production of metals. There does not appear, however, to have been any serious attempt to co-ordinate and render available even such information as has been collected by these Departments, and it is certain that there has been considerable overlapping and duplication of effort, with corresponding waste and confusion.

It is, we submit, obvious that the overlapping and confusion will be seriously increased if the various Technical Committees appointed by the Advisory Council attempt to collect the information which is essential to enable the beneficent object of the Committee of the Privy Council to be attained, in its wider aspects, in regard to the mineral and metal industries.

We respectfully urge this view upon the serious attention of the Advisory Council, as already there are evidences of

increasing overlapping and consequent waste of time and energy, which we believe it is one of the main purposes of the Committee of the Privy Council to eliminate as far as possible.

In the opinion of the Institutions represented by us the organisation of a central Department of Minerals and Metals is imperatively necessary in the public interest, and the work of organisation, which will necessarily take much time to complete, should be commenced at the earliest possible moment.

It cannot be doubted that if a properly-organised and efficiently-conducted Department of Minerals and Metals had been in existence, much valuable time, many lives, and vast sums of money would have been saved to the nation in the conduct of the present war, and much of the cost and inconvenience to British industries depending largely for their raw materials on mineral products would have been saved, with corresponding advantages to the prosecution of the war and to many industries.

A Department of Minerals and Metals should not only be in intimate relationship with the Geological Surveys and Mines Department of the Dominions, but also with the organisations representing the different branches of the mining and metallurgical industries, whose co-operation in the work of the Department should form a vital part of its machinery.

The Geological Surveys of Great Britain and Ireland, and the Museum of Practical Geology, should also form an integral part of the Department.

The functions of the Department should be active and constructive. All overlapping by other Home Government Departments, and also by the Institutions representing the industries, should be absolutely prevented.

The duties of a Department of Minerals and Metals would include:—

(1) Arrangements for expediting the completion of mineral surveys of the United Kingdom and of the Crown Colonies and other British Possessions.

(2) The systematic collection and co-ordination of information bearing on the occurrence, uses, and economic value of minerals and their products; special attention being devoted to securing industrial applications for newly discovered minerals or metallurgical products, and to finding mineral materials required for new metallurgical products or inventions. Some of this information should be promptly and widely disseminated in summarised form to those interested in the industries, through the medium of the existing publications of the Institutions directly concerned.

(3) The investigation of all questions and problems relating to the utilisation of the mineral or metallurgical resources of the Empire.

(4) The co-ordination and dissemination of information on mining laws, development of mineral areas, output, processes of extraction, plant, capital employed, markets, &c., &c.

(5) A general review from time to time of the developed and undeveloped mineral resources, and of the position of each mineral or metal, to ensure that the mineral wealth of the Empire is being exploited with due regard to Imperial interests.

(6) Generally, to advise the Imperial Government on all questions bearing on the mining and metallurgical industries. To perform this function efficiently, it is essential that complete information should be available, and also that the industries concerned should be consulted through their respective organisations.

We feel sure that the Advisory Council will fully appreciate the urgency of the question, and the necessity for prompt action, so that the process of co-ordination may be inaugurated at once.—We are, Sir, Your obedient Servants,

WM. BEARDMORE, President, G. C. LLOYD, Secretary,	*The Iron and Steel Institute.*
GEORGE BEILBY, President, G. SHAW SCOTT, Secretary,	*The Institute of Metals.*
W. THORNEYCROFT, President, L. T. O'SHEA, Hon. Secretary, P. STRZELECKI, Secretary,	*The Institution of Mining Engineers.*
C. MCDERMID, Secretary, EDGAR TAYLOR, President,	*The Institution of Mining & Metallurgy.*

SCIENTIFIC AND INDUSTRIAL RESEARCH.

REPORT OF THE ADVISORY COUNCIL.

(*Concluded from page 251.*)

The Possible Sphere of Special Research Institutes.—Many other examples might be given of the kind of work we mean; but when the scientific bases of a whole trade are in question some other machinery must be devised. Dr. Mees in his pamphlet expresses the view that at this point the university ceases to be a suitable agent. It may be that in America this is so, though there is no country, we imagine, in regard to which it is less safe to generalise, and certainly German practice tends to confirm his doubts. Yet we are not sure that under the conditions prevailing in the United Kingdom a place may not be found for the universities in some at least of these more comprehensive and complicated researches. We must not forget how much they have done already by means of separate technological departments closely related to the industries. The metallurgical department at Sheffield, the departments of tinctorial chemistry and of leather at Leeds, the engineering departments of the Royal Technical College, Glasgow, the departments of economic botany and of engineering at the Imperial College, the departments of mining and of brewing at Birmingham, are obvious examples. But we believe that the present organisation of such departments will need modification and development if they are successfully to carry the burden that will be put on them. But the advantages are obvious, especially at the present stage of our scientific development. In the first place, it will be easier to attract the support of the trades if provision is made for training their higher staff as well as for investigating their difficulties. In the next place, it ensures the continued contact of the research worker with advanced students—an inestimable benefit in the opinion of all the best authorities. Finally, it enables us to use to the utmost advantage the very limited number of original workers available either for research or for teaching. This is a consideration of very practical importance, for if research institutes were in all cases to be established independently of our universities and colleges we should be in grave danger of depleting our educational institutions before they have had time to produce the number of workers which the industries will need if progress is to be made. At the same time, we are far from thinking that the university connection will always be either practicable or to be desired. In some cases now before us it will probably be the best way of proceeding; in other cases, where a powerful industry and very complicated problems are concerned, it may not. We shall approach each case with an open mind, and so far as possible reserve to ourselves the opportunity of reconsidering at suitable intervals any arrangements that we recommend to the Committee of Council.

Research and Government Departments.—We have confined our remarks so far to those aspects of our work which are specially emphasized in the White Paper, and which are undoubtedly the most urgent; but scarcely less important than the encouragement of research in our educational institutions and our factories is a due correlation of the research activities of the Government, or—as we should rather say—of the Governments of the Empire. We believe this can best be achieved by the free exchange of information given in a spirit of hearty co-operation. Accordingly Mr. Henderson, realising that the activities of the Committee of the Privy Council and its Advisory Council might create serious confusion and overlapping—especially at the present time—if they proceeded in ignorance or neglect of the work done by the departments of State in the same field, announced in the White Paper that arrangements would be made on which the Council would "keep in close touch with all Government Departments concerned with or interested in scientific research." The means adopted to this end has been of the greatest assistance to our labours, and we hope has been convenient to the departments concerned.

Research and the Empire.—The Secretary of State for the Colonies who appoints an assessor on our Council was in practice responsible for the administration of the Imperial Institute under an arrangement with the Board of Trade, to

whom the management had been entrusted under the Act of 1902. This arrangement has since received legislative sanction in the Imperial Institute (Management) Act, 1916, and an Executive Council of 25 members has taken the place of the Advisory Committee set up by the Act of 1902. Among the members of the new Executive Council of the Institute is Mr. Richard Threlfall, a member of our Council, and formerly Professor of Physics in the University of Sydney, who has been appointed by the Secretary of State for the Colonies, on the nomination of the Lord President of the Council. There is now accordingly a double link between the Imperial Institute and ourselves, which, in itself, has opened up at least the possibility of relations with the dominions over the seas. Almost simultaneously the Imperial College of Science and Technology applied for and was granted an amendment of its charter in order to enable the overseas dominions to be represented on its governing body. But the needs which led the mother country to formulate a scheme for the organisation and development of scientific and industrial research had been realised with equal conviction in other parts of the Empire. The Victorian Government, in a dispatch dated October 5th, 1915, to the Secretary of State for the Colonies, stated that they were desirous that the scheme described in the White Paper [Cd 8005] should be "extended to the dominions, in order that the State of Victoria may receive the benefit of this most important movement," a proposal which was endorsed by the Premier of New South Wales, and the Commonwealth Government at a later date decided to work out a plan for the whole of Australia. A strong committee, appointed by the Commonwealth Government, reported in favour of the establishment of a national Research Institute, under the charge of three directors, with an Advisory Council, and the Government accepted the proposal in its main outlines. Meantime the Committee of Council had submitted a memorandum to the Colonial Office for communication to the dominions, containing suggestions as to the various ways in which the home organisation might co-operate with similar organisations in other parts of the Empire. During his recent visit to this country, Mr. Hughes, the Prime Minister of Australia, honoured the Advisory Council by attending one of our meetings and explaining the intentions of his Government and their desire for a free exchange of views with the Council and its officers. On that occasion the great importance of the establishment of a central clearing house of information as to research was urged upon us, and it will be clear from what we have said already that, subject to the approval of the Committee of Council, we are prepared to do what we can to supply this need.

In Canada a similar movement has begun, and an Order in Council was issued on June 6th establishing machinery similar to that in this country for the encouragement of scientific and industrial research. Sir George Foster, the Canadian Minister of Trade and Commerce, kindly attended a recent meeting of the Council and explained the proposals of his Government, which are based on their conviction that each part of the Empire should organise its present machinery for research before attempting collaboration with the Mother Country. The Canadian Pacific Railway has also recently set up a department for the scientific investigation of the mineral wealth, and the hydro-electric and chemical resources of the Dominion, especially in those districts served by the railway. It proposes to encourage the utilisation for industrial purposes of minerals which have hitherto been neglected or exported to foreign countries for manufacture, and to investigate the by-products in existing industries heretofore wasted or insufficiently utilised. This company has resources adequate for the conduct of research on a fundamental scale, and we shall watch with interest the development of its plans. The New Zealand Government also have the matter under consideration, for they have referred the memorandum of the Committee of Council to a board constituted under the Science and Art Act, 1913, "for opinion and advice." We have not yet had an opportunity of considering in detail the possibility of co-operation with the Indian Government, but the Messrs. Tata, the generous founders of the Indian Institute of Science at Bangalore, have assured us of their desire to co-operate in any researches which we may wish to initiate in India. The organisation of research within the Empire must inevitably be a plant of slow growth, yet we think it augurs well for the future, that thought should move in parallel lines in places so remote and under conditions so various. It is obvious that the existence of such organisations throughout the Empire would immensely facilitate our own task by enabling us to enlist the best brains for the attack on problems of Imperial significance irrespective of the researcher's domicile.

It seems probable that one of the first and most necessary preliminaries to joint research in the stricter sense will be found to be the making of a systematic survey of the mineral and other resources of the Empire. Our attention has already been drawn to this need from many sides. The right organisation for the purpose is not easy to devise, and it is not yet clear where the responsibility should rest for co-ordinating the work of the several Government surveys, and for collecting unofficial information which may often be of great value. We are disposed to think that no machinery less independent than that of a Government office would suffice, but the whole question will doubtless be considered by the Committee under the chairmanship of Lord Balfour of Burleigh, appointed by the Prime Minister to consider the commercial and industrial policy to be adopted after the war, with special reference to the conclusions reached at the Economic Conference of the Allies, and to a number of other questions among which are: To what extent, and by what means, the resources of the Empire should and can be developed; and to what extent, and by what means, the sources of supply within the Empire can be prevented from falling under foreign control.

Conclusions.—We have not attempted in this report to describe or even to make reference to all the various researches which we have recommended the Committee of Council to aid, still less to detail the larger and more comprehensive plans which are under consideration, for it seemed to us more important in this, our first report, to explain the principles which have guided us in our work, to call attention to some of the difficulties which will have to be overcome, and to record the spirit of goodwill and co-operation with which we have been met. The experience we have already gained in dealing with these researches, and other applications and proposals now before us, enables us to trace the main directions in which the work of the Committee and the Advisory Council will probably lie during the coming years, and to foresee some of the more important conditions which will need to be secured if the object for which the Committee of Council was established is to be attained. It may be useful in conclusion to summarise those that appear to us necessary for the success of our work.

If we were asked to state these conditions in the shortest possible terms we should reply: First, a largely increased supply of competent researchers; secondly, a hearty spirit of co-operation among all concerned, men of science, men of business, working men, professional and scientific societies, universities and technical colleges, local authorities, and Government Departments. And neither condition will be effective without the other.

The first condition of success cannot be secured rapidly at any time, and for the moment is out of the question. Before the war the output of the universities was altogether insufficient to meet even a moderate expansion in the demand for research. The annual number of students graduating with first and second-class honours in science and technology (including mathematics) in the Universities of England and Wales before the war was only about 530, and of these but a small proportion will have received any serious training in research. We have frequently found on enquiry that the number of workers of any scientific standing on a given subject of industrial importance is very limited.

It is in our view certain that the number of trained research workers who will be available at the end of the war will not suffice for the demand that we hope will then exist. We are too apt to forget in this country that with industry as with war, a brilliant group of field officers, and even a well-organised general staff, needs armies of well-trained men in order to produce satisfactory results. Our people have no reason to fear or envy the scientific pioneers of other races. They have had, and will probably continue to have, their full share of the outstanding minds to which each century gives

birth, but as time goes on the sphere of the solitary worker tends to become relatively, if not absolutely, smaller. Effective research, particularly in its industrial applications, calls increasingly for the support and impetus that come from the systematised delving of a corps of sappers working intelligently, but under orders. We have not yet learned how to make the most of mediocre ability—particularly in things of the mind—yet without the scientific rank and file it will be impossible to staff the industrial research laboratories which are coming, as to fight a European war with seven divisions. There is as much place and need for plodding labour in scientific research as in other kinds of work.

The responsibility for dealing with the grave situation which we anticipate rests with the education departments of the United Kingdom. We shall be able to do something to encourage a longer period of training by the offer of research studentships and the like; but that will not suffice. It is useless to offer scholarships if competent candidates are not forthcoming, and they cannot be forthcoming in sufficient numbers until a larger number of well-educated students enter the universities. That is the problem which the education departments have to solve, and on the solution of which the success of the present movement, in our opinion, largely depends.

As regards the second condition of success, progress in co-operative effort is undoubtedly being made in many directions, and we have mentioned some instances of it. But we wish to point out that there are specially strong reasons for more co-operation between the various British firms in each industry, and between the industries and the State, in the furtherance of research. The particular difficulties encountered in the day-to-day routine of manufacture, the possibility of improving a process, of diminishing cost of working, enlarging output or enhancing the quality of a product, are matters which we may expect the individual firm to attack directly it begins to believe at all in the application of science to its own trade. But this is not enough. We are looking to the growth of a demand for fundamental research, and fundamental research, as we have seen, requires a very large expenditure on brains and equipment. It also requires continuous effort. The firm that starts out upon this quest must either be very powerful or it must find the necessary strength in association with others. If the general level of manufacture can be rapidly raised by co-operative effort in the exchange of information between firms, and in the support of national trade institutes for research, as well as in the improvement of the conditions and efficiency of labour, this country will have gone far towards establishing its industrial prosperity on a firm basis.

The economic problem lies outside our province, but it is an important aspect of the great issue with which we are concerned, and we do not believe that issue can be met effectively unless a co-ordinated advance is made simultaneously on the whole front. We think it possible that the voluntary efforts of manufacturers in friendly union which enabled the problem of munitions to be rapidly solved, may lead to a new kind of reciprocity between firms which will avoid the evils both of monopoly and of individualism. We think that as people have learned to combine against the risk of fire or shipwreck without losing either initiative or freedom, so firms may come to look upon expenditure for research as a necessary kind of insurance. It is certain that the costs to be met will, on any adequate estimate, have to be counted not by tens of thousands, nor even by hundreds of thousands.

We have repeatedly spoken in the pages of this report about the initiation of particular researches and the solution of particular problems. It has been the inevitable concomitant of the line of procedure we have advisedly selected. But if it is supposed that modern industry can be developed or even maintained by a process of detailed investigations, a series of particular enquiries, however careful, the time, trouble, and expense involved will be largely wasted. Such a supposition is based on fallacious conceptions of the manner in which scientific research proceeds, and of the way in which the great scientific industries have been built up. It is impossible for the most acute investigator to be sure that a particular line of research will lead to a positive result; on the other hand, it will often suggest a diverging enquiry that, if followed up, may produce results even more valuable than the original question. Such loose ends litter the laboratories of firms which confine themselves to questions of the moment. They lead straight to the basic theory of a subject, to the roots that strike down into pure science. They are infinite in number, and interminable, as the man of pure science knows well; but they also often yield results that revolutionise those industries which are empirical in their methods—as what industry is not?—and give that control over nature which it is the object of all science, whether pure or applied, to secure. The discovery of the structure of the indigo molecule led not merely to the synthetic manufacture of this blue dye, but has enabled the chemist to produce a number of new substances of analogous structure and different shades of colour.

Research of this order does not cease when a problem—even if it be as complicated as synthetic indigo—has been solved. It must be continuous in its operation, and its ramifications will spread as knowledge grows. It will inevitably tend to bring industries into intimate relation, which are at present independent of each other, to transform what has hitherto been crafts into scientific industries, and to require co-operation not only between different firms in the same industry, but between groups of industries in a continuously widening series of inter-related trades. The forces which are at work in this direction have elsewhere found their expression in connection with the trust and the combine; but we believe, if the real nature of these forces is clearly grasped, that it will be possible to organise them for the benefit not only of the industries but of the nation as a whole.

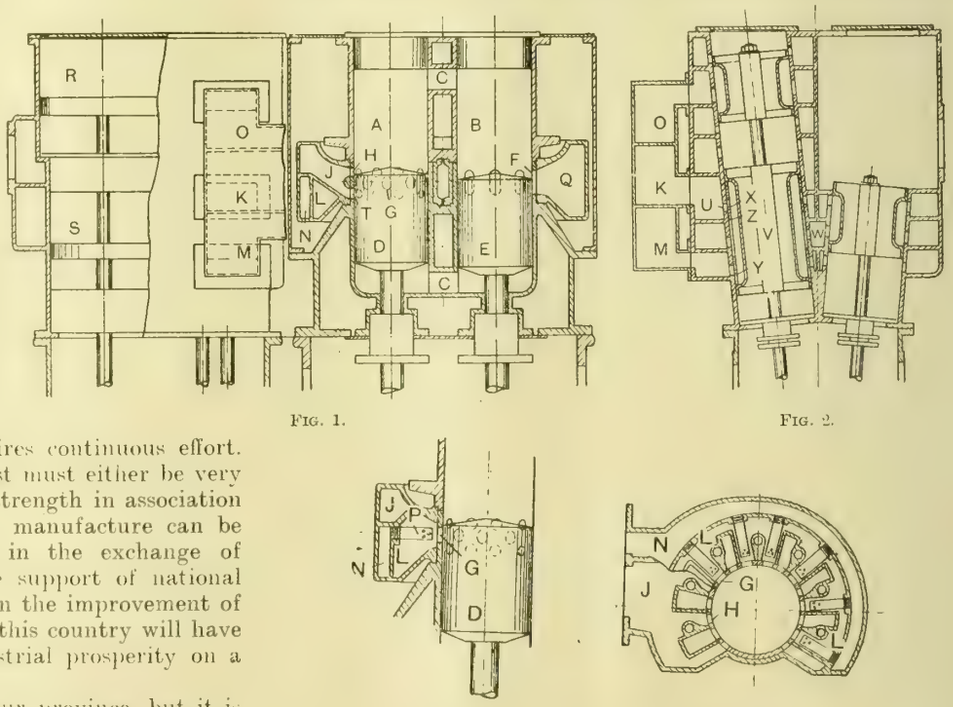


FIG. 1. FIG. 2.

FIG. 3. FIG. 4.

CHARGING OF TWO-CYCLE GAS ENGINES.

CHARGING OF TWO-CYCLE GAS ENGINES.

A PATENT recently granted to Messrs. Mather & Platt, Ltd., and John Davidson, of Park Works, Manchester, relates to the distribution of the working fluid for two-cycle internal-combustion engines, and particularly to the valveless type of engine in which two pistons are used, one of which controls the admission and the other the exhaust. The main object of the invention is to provide a simple means of distributing the air and gas so as to ensure a pure air scavenge, under all con-

ditions of load, and a proportioned delivery of mixture which can be entirely under control of the governor. Figs. 1 to 4 show a double-acting engine with gas and air charging pumps combined with the engine. A and B are the two working cylinders, with connecting passages at C. The two pistons D and E work together and are coupled to the same crank, but the crank to which the exhaust piston E is coupled leads slightly, in order to open the exhaust ports F—and so relieve the pressure in the cylinders—before the scavenge air is admitted. Around the inlet cylinder A a belt containing three separate passages J, L, N is formed. Three rows of ports are also formed in the cylinder barrel as shown. The centre row G are the mixture ports, and the outer rows H and T are the scavenge ports. The scavenge ports are in direct communication with the air pump by means of the passage J round the belt, and the connecting passage K. The mixture ports G admit both gas and air. The passage L round the belt is in direct communication with the air pump—but entirely separated from the passage J—by means of connecting passage M. The gas is delivered from the gas pump through passage O to belt passage N, and escapes through the small perforated pipes P into the mixture ports G, where it mixes with the air delivered from passage L at the entrance to the cylinder. Another belt Q is formed round the exhaust cylinder B, to carry away the exhaust when escaping from ports F. R is the gas pump, and S the air pump, the inlet and outlet to same being controlled by means of piston valves driven from eccentrics fixed to the crankshaft. Between the piston valve of the air pump and the inlet cylinder A is placed another piston valve V, driven from the same spindle as the gas piston valve. The object of this valve is to distribute the air to the scavenge passage K and the mixture passage M. Delivery from the air pump takes place through ports W to the space around valve V, and the cut off edges of valve V at X, Y, Z control the passage of air to the passages K and M.

Assume that the working pistons D and E are nearing the end of their downward stroke. The exhaust piston E first uncovers the exhaust ports F a little, and the pressure in the cylinders is reduced. Immediately afterwards the inlet piston D uncovers the scavenge ports H, and pure air is admitted to drive out the remaining exhaust gases. As the piston D moves further downward, it uncovers the mixture ports G, and a charge of gas and air flows into the cylinder. Almost at the same moment the delivery of air through the scavenge ports H is cut off, as the edge X of valve V, which is now moving upwards, cuts off the supply of air to passage K and so to the scavenge passage J in the belt. While the edge X closes passage K, edge Y opens the supply of air to mixture air passage M, and so to passage L in the cylinder belt. The charge continues to flow into the cylinder until the piston D closes the ports G on the upstroke, but just before it closes the scavenge ports H, the edge Z of piston valve V slightly uncovers the scavenge air port U and allows pure air to flow through the passages K and J, and so clear out any mixture which may have been pressed into the scavenge ports H of the inlet cylinder A. The object of this second blow through is to ensure a pure air scavenge when the ports are again uncovered. The order of events for the top half of the cylinders only has been described, as for a single-acting engine, but precisely the same events take place on the bottom side in the case of a double-acting engine as shown in the illustrations.

INDUSTRIAL APPLICATIONS OF ZINC.*

BY ERNEST A. SMITH, A.R.S.M., M.INST.M.M.

THE zinc obtained by the distillation process in America is generally sufficiently pure for industrial purposes, but in Europe it may contain from 2·0 to 3·0 per cent. of lead, about 0·3 per cent. of iron, and small amounts of cadmium. To remove these impurities the metal is liquated in large reverberatory furnaces with sloping hearth, holding from 20 to 30 tons of metal. The refined metal is cast into slabs about 17½in. by 8½in. by 2½in., weighing from 45lbs. to 50lbs., and bearing the name of the smelting company. The following analyses of brands of virgin spelter, by J. S. G. Primrose, may be taken as typical:

Brand.	Lead.	Iron.	Cadmium.	Tin.
	Per cent.	Per cent.	Per cent.	Per cent.
Upper Bank (English)	2·55	0·15	0·09	0·05
V.M.G. (Belgium)	0·66	0·26	Nil	0·03
Vieille Montagne (Belgium)	2·00	0·04	0·07	Nil
Freiberg (Saxony)	1·03	0·04	0·02	0·07
Lazyhutte (Upper Silesia)	1·12	0·02	0·017	Nil.
Lipine Electrolytic (Upper Silesia)	0·06	0·01	0·005	0·02

It is necessary to differentiate between spelter and fine zinc, for which latter there is a growing demand. The highest grades of zinc are generally prepared by the employment of pure ores, and by redistillation of ordinary spelter, but some are prepared by electrolysis. Zinc intended for the manufacture of brass which has to undergo severe mechanical treatment, as in the manufacture of cartridge cases, should be of good grade and contain not more than 0·1 per cent. lead, and 0·05 per cent. of iron.

The galvanised iron industry probably accounts for about 60 per cent. of the world's consumption of spelter, while the manufacture of brass probably utilises another 20 or even 25 per cent., the remaining 15 to 20 per cent. being used for conversion into sheets and for minor uses, such as the production of alloys. Formerly the only process adopted for galvanising was that invented by Crawford in 1837 which consisted in dipping the sheets, wire, or manufactured goods into a bath of molten zinc, after preliminary treatment by "pickling" or "sand-blasting"—the method being known as "hot galvanising." During the last few years, however, this method of obtaining a zinc coating has had formidable competitors in the deposition of zinc electrolytically, and the process known as "Sherardising."

The advantages of the electrolytic method are mainly: (1) greater economy in the use of the metal; (2) more complete control of the thickness of the coating on various surfaces; and (3) its applicability to the covering of iron or steel articles which have been subjected to any special heat treatment—thus necessitating coating at the ordinary temperature of air and not at that of molten zinc. On the other hand, the surface is dull or dead, and not so pleasing in appearance as that obtained by the older method. The hot galvanising process was responsible for the production of practically all of the 850,000 tons of galvanised sheets and wire exported from the United Kingdom in 1913.

The dross obtained at galvanising works is frequently concentrated to about 9 per cent. iron by remelting and skimming off the purer spelter from the top, after which it is redistilled. The enormous prices of zinc of the past year have practically brought galvanising to a standstill, and has led to the adoption of substitutes, such as "galvanising" with lead, which may in some cases prove to be permanent. Although it is not easy to alter the current of consumption of a world-wide commodity like galvanised sheets, the possibilities of substitutes, once the buyer is familiarised with them and finds them cheaper, is obvious. Experience to-day suggests that substitutes for zinc are having their opportunity, and will doubtless hold some of the ground they have temporarily gained.

The electro-deposition methods of "galvanising" are now prominently to the fore and their use is increasing, since they possess several important advantages over hot galvanising. Although a large number of solutions have been tried for electro-zincing, the general consensus of opinion amongst practical operators is that solutions of the sulphate, either alone or with other salts, give for general purposes the most reliable results obtained up to the present, with the minimum of trouble in working.

In the process of dry galvanising, known as Sherardising, which is growing in importance, the iron and steel articles, after being thoroughly cleaned by pickling, are heated in metal drums, or boxes, in contact with zinc dust at a temperature of from 260° C. to 425° C. Partial vaporisation of the zinc dust takes place, the vapour condensing on the surface of the iron articles. It is stated that the best results are obtained when the zinc dust contains 50 per cent. of metallic zinc. The inner layers of the coating are said to consist of a zinc-iron alloy. The Sherardised surface is light grey, with

* From a paper entitled "The Development of the Spelter Industry," read before the Institute of Metals, September 20th, 1916.

matte finish, but it is capable of receiving a high polish and made to resemble nickel plate. The Sherardising process is economical, and yields a superior product. This process will doubtless receive more attention in the future than has hitherto been accorded to it.

Zinc exhibits its greatest degree of ductility and malleability between 100° C. and 150° C., between which temperatures it is rolled into sheets. The metal used for this purpose must not be too high in lead and iron. According to Prost and Van de Casteele, lead does not interfere with the rolling qualities when below 1·25 per cent., but that any increase above this is injurious. Cadmium is injurious if above 0·25 per cent., whilst arsenic and antimony are harmful from 0·02 per cent. upwards, arsenic in particular having a very hardening effect. As little as 0·01 per cent. of tin has a bad effect. Copper below 0·08 per cent. has no effect, or iron below 0·12 per cent.

In the manufacture of rolled zinc the usual practice is to cast the metal into thin plates, or ingots, which while still hot are rapidly passed through rolls until the desired thickness is attained. Most of the zinc rolling is done on the Continent, where the sheet metal is largely used for roofing. The chief rolling mills are in Silesia and Belgium. Zinc rolling is also carried on to a limited extent in America and in this country.

Within recent years thick rolled zinc plates have been used to prevent corrosion of the plates in marine boilers. For this purpose they are drilled and bolted into position. Owing to its being highly electro-positive the zinc is first attacked by the corrosive influences, and can be renewed when necessary. Rolled zinc plates of specially high quality find, according to Moulden, important use in the photographic reproduction processes known as photo-zincography, and in photo-etching. Thin zinc sheeting stamped with varied ornamental designs in relief has of recent years found a very considerable use for ceilings.

Mention may also be made of the use of thin sheet zinc for domestic articles, such as bath-tubs, pails, toys, &c. Zinc rods find application in battery cells for electrical work. They are prepared for this purpose by casting, rolling, or extruding the metal. It is stated that the life of rods made from fine zinc is much longer than those made from ordinary spelter. In this connection it may be noted that, as the result of a series of tests on the corrosion of commercial zincs of various compositions, E. Prost arrived at the following conclusions. The presence in zinc of lead, cadmium, or iron in larger proportion than usually found in refined zinc leads to increased corrosion by acids. Minute quantities of arsenic, antimony, copper, or tin, especially the two former, accelerated very pronouncedly the rate of corrosion, more or less independently, of the actual percentage of impurity present.

The employment of zinc for the manufacture of seamless pipes for water supply has been advocated in recent years. The pipes are made from pure, "hard" zinc, and have a diameter up to 80 mm. They can be tin-lined if required. Two pipes can be joined in the usual manner by widening the end of one and inserting the end of the other, or by covering the adjacent ends with a sleeve, and soldering. Tin solder is used, preferably with a stearine flux. The manufacture of the pipes is simple, and their bending is easy. The pipes are as useful for water supply as lead pipes, and have the advantage of being much safer from a hygienic standpoint, as no injury has been found to arise from the traces of zinc which are dissolved by water. Zinc is cheaper than lead for this purpose, and on account of its lightness the pipes do not require such strong wall supports as lead pipes. A pressure of 500 atmospheres is required to burst the pipes. These pipes cannot, however, be used for a hot water supply, on account of the great expansion of zinc. In some recent tests by Rinck, tap-water of medium hardness was sealed up in large zinc pipes with air excluded. After a year the amount of dissolved zinc was 2 to 3 milligrammes per litre. Physiological tests over a long period with water containing 7 to 8 milligrammes of zinc per litre gave no indications of injurious results.

Amongst the applications of metallic zinc must be included the use of so-called zinc dust, or blue powder. In addition to its use in the Sherardising process, it is now largely used as a precipitant for gold in the cyanide method of gold extraction, and is gradually replacing the zinc shavings formerly used for this purpose. Zinc dust is also largely used as a reducing agent in the dyeing and textile industries, and is useful as a precipitant for the removal of impurities, such as copper, antimony, &c., from electrolytic solutions. The commercial value of zinc dust depends upon its content of zinc in the metallic state, and the best grades, according to Moulden, contain from 86 per cent. to 92 per cent. of zinc in the metallic condition. In 13 samples of commercial zinc dust from different sources, examined by Herz, the percentages of lead, cadmium, and zinc oxide varied between 0·15 and 5·20, 0·00 and 3·90, and 6·30 and 17·85, respectively.

Metallic zinc is also used in the Parkes process for the desilverisation of argentiferous lead, and for the reduction of silver chloride produced in the refining of gold bullion. Small percentages of zinc also enter into the composition of a large number of commercial alloys. In India it has long been used

*Typical Zinc Alloys.**

Alloy.	Composition per Cent.								Remarks.
	Zinc.	Copper.	Tin.	Lead.	Nickel.	Anti-mony.	Iron.	Alu-minium.	
Anti-friction Metals—									
Anti-friction metal	85·0	5·0	...	...	...	10·0	...	...	
Babbits' metal (so called)	69·0	4·0	19·0	5·0	...	3·0	...	...	
Bearing metal	8·0	82·0	10·0	...	...	...	...	...	For locomotive axles.
" " hard	2·0	82·0	16·0	...	...	...	...	...	
" " medium hard	6·0	67·5	21·5	...	...	...	...	...	
" "	20·0	76·0	3·0	1·0	...	...	...	...	Daimler motor-bus bearings.
Lumen bearing metal	85·0	10·0	...	...	...	...	...	5·0	
Special " "	82·0	12·0	...	...	...	...	...	6·0	
Vaucher's alloy	75·0	...	18·0	4·5	...	2·5	...	...	For journal lining.
Brasses—									
Aluminium brass	38·0	60·0	...	...	...	...	...	2·0	
Best yellow brass	30·0	70·0	...	...	...	...	...	...	Sheet, wire, tubes, cartridges, &c.
Brass	5·0	94·5	...	...	...	...	0·5	...	High-pressure turbine blades.
"	29·0	70·0	1·0	...	...	...	...	...	Condenser tubes. Admiralty specification.
" to be machined	38·0	60·0	...	2·0	...	...	...	...	
Cast brass (so called), very variable	43·0	57·0	...	...	...	...	...	...	
Naval brass	37·0	62·0	1·0	...	...	...	...	...	Admiralty specification.
Ordinary brass	33·3	66·6	...	...	...	...	...	...	Wires, sheets, &c.
Aich's metal	38·0	60·0	...	...	...	...	2·0	...	
Delta metal (average composition)	36·0	60·0	2·0	1·0	...	...	1·0	...	
Muntz metal	40·0	60·0	...	...	...	...	...	...	Sheathing.
Parson's white "brass"	30·0	5·0	65·0	...	...	...	...	...	
Sterro metal	55·5	42·0	...	...	...	...	2·5	...	
Brazing solder	50·0	50·0	...	...	...	...	...	...	
Bronzes—									
Coinage bronze (British)	1·0	95·0	4·0	...	...	...	...	...	
Gun metal	2·0	88·0	10·0	...	...	...	...	...	Admiralty No. 1.
" "	1·0	86·0	13·0	...	...	...	...	...	Admiralty No 2A to resist high pressure.
Manganese bronze	42·0	54·5	1·5	...	...	...	1·0	0·5	0·5 Mn (composition varies).
"*German Silvers*" (so called)—									
Firsts	28·0	56·0	...	...	16·0	...	...	...	
Seconds	24·0	62·0	...	...	14·0	...	...	...	
Thirds	32·0	56·0	...	...	12·0	...	...	...	
Fourths	35·0	55·0	...	...	10·0	...	...	...	
Fifths	36·0	57·0	...	...	7·0	...	...	...	
Miscellaneous—									
Admiralty metal	28·5	1·5	70·0	...	...	...	...	...	For work under water.
Ashberry metal	1·0	2·0	80·0	...	...	14·0	...	...	Other metals 3 per cent.
Motor alloy	10·0	2·0	...	...	...	...	...	88·0	Light alloy for motor-car work.
White button metal	80·0	20·0	...	...	...	...	...	...	

* Compiled from tables in Law's Alloys, and other sources.

by native silversmiths for alloying with silver for the production of silver wares. Alloys used for this purpose examined by the author contained on an average 90 per cent. silver and 10 per cent. zinc.

The accompanying table shows the composition of typical industrial alloys in which zinc is an important constituent. Amongst the newer zinc alloys must be mentioned those of aluminium-zinc, which are being largely used for light castings in the automobile industry. For this purpose the alloys contain usually from 10 to 20 per cent. of zinc, with the addition of a small quantity of copper. The alloys in the aluminium-zinc series containing more than 40 per cent. appear to be of no practical value. The alloys comparatively high in aluminium are very light and strong. Those containing up to 15 per cent. of zinc are soft enough to be rolled or drawn, while beyond this amount the alloys are hard and more suitable for castings, as they are easily worked.

In aluminium founding zinc is largely used as an alloying metal, up to one-third the weight of the aluminium; it assists in the production of sound castings, and incidentally raises the tenacity very materially. In the opinion of a recent writer, the suggestion that the aluminium-zinc alloys are unreliable and likely to break down through disintegration, has not been proved to be a serious difficulty. The writer further points out how essential it is to control the casting temperature of such alloys. From tests made by Bancroft, it appears that with the addition of zinc to aluminium the tensile strength gradually rises to 15·5 tons per square inch at 30·0 per cent. zinc. There is then a steady fall to 11·0 tons, with 96 per cent. zinc, and with further additions the decrease in strength is very rapid. The ductility of aluminium is lowered by zinc, falling to 5·0 per cent., when 10 per cent. of zinc is present. All alloys containing more than 10 per cent. of zinc give approximately the same ductility, namely, about 2·5 per cent. The industrial importance of the aluminium-zinc alloys is gradually being more fully recognised.

With regard to zinc in alloys for bearings, it may be stated that at least 75 per cent. of the car journal bearings in use on United States railways contain upwards of 2 per cent. of zinc. In a recent investigation on the effect of zinc on the mechanical properties of copper-tin-lead bearing alloys, Clamer concluded that alloys containing not less than 65 per cent. of copper, and approximately 5 per cent. of tin, up to 20 per cent. of lead, and up to 5 per cent. of zinc, should be satisfactory for all classes of car journal bearings. With an increase in the amount of lead, the zinc content should be correspondingly diminished.

In the author's opinion, the extension of the use of zinc in the future will be dependent in no small degree on the discovery of new alloys suitable for industrial purposes. Much work yet remains to be done in studying the influence of the addition of metals such as nickel, cobalt, and chromium on commercial zinc alloys. Thus research has shown that the properties of certain brasses are considerably improved by the addition of small amounts of nickel.

Of the various compounds of zinc of commercial value, zinc oxide is by far the most important. It is largely used as a pigment, under the name of zinc-white, and is valued for its lack of discoloration, as it is not blackened by sulphuretted hydrogen like white lead, for which it is a substitute. Although it lacks the body and opacity of white lead, and is non-poisonous, it has good covering power. The zinc oxide of commerce is frequently adulterated with barium sulphate, sometimes to a very considerable extent. Considerable quantities of zinc oxide are also used in rubber and linoleum manufactures, and in medicine it appears in zinc ointment. The bulk of the zinc oxide of commerce is made direct from zinc ores in America, while it is also prepared in Europe by the combustion of metallic zinc.

Other compounds of zinc of industrial importance are zinc sulphate, or white vitriol, and zinc chloride. Both these are prepared from zinc scrap by dissolving it in sulphuric acid and hydrochloric acid respectively, and crystallising out the resulting salt. Zinc sulphate is used in medicine and in the textile industries as a mordant, and in the manufacture of glue, where it acts as a clarifying agent and preservative. Within recent years zinc sulphate has found its greatest application in the manufacture of lithopone, used as a pigment as a substitute for the more costly zinc oxide.

Lithopone, which is a mixture of zinc sulphide and barium sulphate produced by combined precipitation using barium sulphide and zinc sulphate, is a stable pigment employed largely in the manufacture of enamel paints. Zinc chloride is mainly used as a preservative for timber, and in the textile industry. It is also used in surgery as a caustic and as an antiseptic.

ELECTRIC POWER DISTRIBUTION.*

BY CHARLES H. MERZ.

"It appears that . . . the coal should be converted . . . into a form in which it is most generally applicable to all purposes without exception, and in which it is most easily applied to all our wants, and is at the same time in a form in which it is most difficult to waste or use improperly.

"We are therefore forced to the conclusion that the only complete and final solution of the question is to be obtained by the conversion of the whole of the coal which we use for heat and power into electricity, and the recovery of its by products at a comparatively small number of great electricity producing stations. All our wants in the way of light, power, heat, and chemical action would then be met by a supply of electricity distributed all over the country." [Extract from Presidential Address of Mr. S. Z. de Ferranti to the Institution of Electrical Engineers in 1910.]

The fuel and other economies and the industrial advantages of dealing with electricity supply for the country as a whole in a comprehensive manner—although appreciated and acted upon by many of those who are in the electric-supply business—are not generally realised to-day by the industrial community or by the State. The compact nature of our industrial districts and their proximity to each other as compared with those of other countries, such as the United States and Germany, makes it economically possible and advantageous to deal with all the power requirements of the community in each industrial area from inter-connected electrical power-distribution systems tapping all sources of power, however scattered, and delivering electrical energy wherever required.

Power undertakings (electric power companies) have been started in most of the industrial areas of the country, and if these were developed throughout the country to the same extent as the system which has been for some time in operation on the North-east Coast, it is estimated that the resultant economies in coal consumption would, in the near future, amount to 25,000,000 tons per annum, and eventually to 50,000,000 or 60,000,000 tons per annum. The immense importance of this to the country is realised even if one only considers the revenue from the sale of this quantity of coal if it were exported.

Another way to look at it is, that if the present industrial power requirements of the country were supplied as cheaply as they could be from such a comprehensive system, there could be such an expansion of industry that present-day power requirements might in no great time be more than doubled. Yet there would be no necessity for increased coal consumption for the simple reason that under such conditions we could use our coal at least twice as efficiently. The economical generation of electricity implies the use of the largest possible prime movers and the running of such machines at as steady a load as possible, since only under these conditions is the highest possible coal economy attainable.

While on the North-east Coast and also in some other districts the generation and supply of electrical power is being developed on correct lines, it is still broadly true to say that as regards the country as a whole the requirements of each municipal area are dealt with separately, with the result that the average size of generating machine employed is certainly not more than a tenth—and probably not more than a twentieth—of what it ought to be. Under such conditions economical coal consumption is impossible. The result is cumulative because, on account of the small size of generating machine employed in public stations and the consequent low economy, manufacturers, railway companies, and other large power users in many districts are still compelled to run power plants of their own, and the use by many manufacturers of their own plant further reduces the average size of power-

* Paper read before Sections B and G of the British Association at Newcastle September, 1916.

generating machines, taking the country as a whole. The only way in which public-supply stations can secure the business of supplying all the manufactories in their neighbourhood is to have generating machines much larger than the largest individual manufacturer could find use for.

If instead of each municipal area being dealt with independently, there were one uniform inter-connected electrical power-distribution system throughout each industrial area, as we now have practically throughout the North-east Coast district, just as there is one railway system throughout the country with a uniform gauge, it is clear that, on account of the magnitude of the resultant load, it would be possible to secure the following results: (1) The largest and most economical generating machines could be installed. (2) These could be located where large sites are available and land is cheap; where coal and water facilities are good; and in the best position, having in view the probable eventual power requirements of the whole community, including factories, railways, and domestic users.

If, on the other hand, each municipal area is dealt with independently, it is clear that in many cases the sites on which the power-generating plant is installed must necessarily be cramped, being in the middle of large towns or congested districts, and that the best coal and water facilities will not be available.

As regards reliability of supply—an essential condition—concentration of generating capacity in large units in conjunction with a main electrical power-distribution system is not a source of danger but the reverse, because by means of such an inter-connected distribution system, one set of generating plan can act as spare to another, whereas, according to the present method of dealing with electricity supply by means of isolated networks, each supplied in general from one generating station, there is no duplication of generating stations or alternative ways of feeding a given area whatever.

Thus, if the community is to benefit by the electric-supply industry being given the maximum chance of development, and if the erection of the most economical generating machines in the best possible positions for economical production is to be secured, and insisted upon, as it must be, by some central authority, the first thing to aim at is the establishment in each industrial district of a common inter-connected electrical power-distribution system.

As has already been indicated, such an ideal may be achieved in this country, on account of its compact nature, to an extent which is not possible in other countries. What is required is co-operation and joint working between the different company and municipal electric-supply undertakings, and this, except in certain cases, has not been possible in the past, due largely to Parliamentary and municipal opposition. If such a complete and unified system of mains could be established in each industrial area, the erection in the best situations of generating plant of the highest economy would naturally follow. That this has not been done in the past is not the fault of the electric power companies, and I am glad to see that many municipal undertakers are now as convinced as the power companies that this joint working is essential.

Another advantage which would follow the erection of plants on roomy and efficient sites, rather than on crowded and inefficient sites, is that this would materially facilitate the extraction of the by-products which can be obtained from the coal before it is consumed in the boiler furnace, wherever it is commercially possible to do so. This process will require large sites. Such by-products may be of as great a value to the community as the residue of fuel, for they include: (1) Sulphate of ammonia and other products of value as manure and as raw material for manufactures. (2) Benzol and other important hydrocarbons, of value in the dye industry, for example. (3) Oils, including motor spirit.

It has been calculated that the requirements of the country in the way of manures, crude oils, oils for marine propulsion, and motor spirit for road traction can all be largely supplied as by-products of our own normal coal consumption if only proper encouragement is given to the establishment of really economical electrical power-distribution systems throughout the country, but it would be out of the question to carry out such schemes in large towns.

(To be continued.)

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Valves for internal-combustion engines. Wilson & Jackson. 12668.
Valves and valve-actuating mechanism for internal-combustion engines. Umpleby. 12831.
Heat retaining covers for use on engine cylinder heads and flanges. Brown. 12905.
Apparatus for determining the "critical" or "conversion" point of samples of iron or steel. Simson. 12993.
Collapsible taps for screw threads. Austin. 13125.
Boring bars. Austin. 13126.
Low water safety apparatus for boilers. Chantrill & Haskins. 13687.
Change gears. Aichele. 14116.
Devices for controlling friction clutches. Brown. 15088.

1916.

Fuel-supply devices for explosion motors. Ellehammer, J. C. Hansen. 840.
Air-pump cylinders of internal-combustion engines. McLaren, W. D., and Welsh, G. M. 2149.
Cylinders for explosion engines. Clench, E. C. S. 2746.
Engine indicating apparatus. Ryder, A. 3147 and 3148.
Thrust bearings. Akt.-Ges. Brown, Boveri, et Cie. 4829.
Split belt pulley. Nyberg, C. S. 4884.
Internal-combustion engines. Wery, E. 4931.
Internal-combustion engines. Weger, C. J. 4933.
Anti friction bearings. Norma Cie. 5350
Anti-friction bearings. Jones, H. Sefton. 5474.
Internal combustion engines. Bugatti, E. 5992.
Air compressors. Black, S. D., and Decker, A. G. 6345.
Internal-combustion engines. Lozinski, C. 6354.
Boring machines. Downs, C., and Littlejohn, W. B. 11085.

ELECTRICAL, 1915.

Electric heaters and electric heating apparatus. Marks. 8508.
Incandescent electric lamps. Simonotti & Simonotti. 12798.
Controllers for electric motors. Dey. 12810.
Arc lamps. Brockie, and Johnson & Phillips, Ltd. 13079 and 13080.
Electric motors. Heys. 13481.
Electric transformers. Thordarson. 13587.

1916.

Electric circuit controllers. Igranic Electric Company. 1246.
Electric heating devices. Heller, L. 4901.
Electrically indicating the presence of saline, alkaline, or acid impurities in feed-water. Crockatt, W. C., and Bromell Patents Company. 5163.
Continuous current dynamos. Allmanna Svenska Elektriska Aktiebolaget. 5391.
Dynamo-electric power-transmission apparatus of the unipolar type. Breslauer, M. 9937.

METAL QUOTATIONS.

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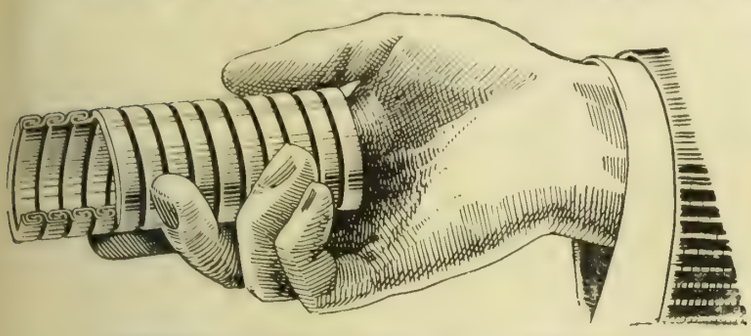

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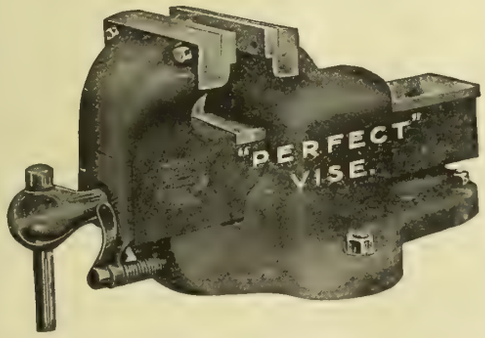

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Compound Boiler Explosions.

COMPOUND boiler explosions, that is the explosion of two or more boilers in the same group together, are happily a rarity, but when they do occur they are without exception exceedingly destructive. The last explosion of this kind in this country occurred at the Distington Ironworks, near Workington, seven years ago, when four large Lancashire boilers out of a group of eleven burst simultaneously* Although we speak of the explosions as simultaneous, investigation invariably reveals that one boiler bursts in the first instance and that the others follow instantly as a result of the disruptive shock. In the case at Distington it was shown almost beyond doubt that one boiler, which had just undergone cleaning, had been isolated from the safety valve—which was fixed on the same outlet as the steam stop valve—by the insertion of a metal diaphragm to prevent leakage from the stop valve annoying some men who were inside the boiler cleaning, and that afterwards those who inserted the diaphragm forgot to remove it. The result was that when the boiler was started again the pressure steadily accumulated in the isolated boiler until it exploded. Such blows on three of the other boilers, two on one side and one on the other, caused them to burst in their turn. This was about the tenth explosion of this kind recorded in this country, and of these at least three were brought about by excessive pressure in precisely the same way as at Distington, namely, by forgetting to remove an isolating plug inserted into the orifice leading to it with a view to prevent the steam from a leaky stop valve entering the boiler and inconveniencing men during the process of cleaning. The moral of these and of the Distington explosion, as we pointed out at the time, was that every boiler should be equipped with at least one safety valve having its own independent connection,

*See "The Mechanical Engineer," October 1st, pages 107, 137 and 143, Vol. XVXI.

so that it could not be isolated even if the orifice to the stop valve was plugged for any reason, while every boiler should be equipped with an independent pressure-gauge. The working of a group of boilers with one or two safety valves only, mounted on a main steam pipe or grouped with stop valves in a single fitting on one orifice, is an arrangement always attended with risk. It may seem remote and appear exceedingly stupid to plug a safety valve outlet, but experience shows that circumstances easily lead to its being done, and unfortunately also to the plug being afterwards overlooked. Our American exchanges to hand bring particulars of another compound boiler explosion that occurred in August at a works at Jackson, Tennessee. In this case three boilers in a group went off together, with disastrous results, the whole factory being wrecked and eight men instantly killed, while a number of others were seriously injured. The details available are somewhat meagre, but it would appear that the middle boiler of the three, all of which were of the multitubular externally fired type, was the first to give way, the centre belt of plating of the three belts of which the shell was composed ripping longitudinally at a riveted seam, and then peeling open almost flat from the other two belts. The effect of this rupture on the boilers to the right and left of it was to cause each of these to rip at a ring seam, and the parts to be blown fore and aft. No explanation is put forward to account for the primary failure of the middle boiler, and the particulars available do not enable one to say whether the arrangement of fittings was satisfactory or not. In the absence of details it is, of course, idle to speculate. It may be noted, however, that the boiler, although it is of a type very common in America, that is, with a plain cylindrical shell with flat ends with tubes running the full length, is not one that commends itself to British engineers. It is no doubt simple and inexpensive to construct, but with dirty water, scale is liable to accumulate on the bottom of the shell, and, being externally fired, cause severe straining and stress throughout the structure. The longitudinal joints of the shell, we note, were made with an overlap, and one or two other features of the explosion suggest that the design and workmanship were not first class, so that in the event of shock from the bursting of the central boiler, those on each side would inevitably follow suit.

Screw-cutting Taps.—The Coventry Ordnance Works, Ltd., Coventry, have recently patented a design of screw-cutting tap, having at each end of the lands the full number of teeth required to cut the screw and having alternate teeth removed from the central parts. The effective diameterof the teeth on the front end of the tap is less than the full effective diameter, so that the teeth on the front end cut the tops of the threads only, and the effective diameters of the teeth gradually increase until the full effective diameter is attained.

Locomotives for Light Road Service.—We have received from the Baldwin Locomotive Works, Philadelphia, a brochure descriptive of locomotives constructed by them for light road service on lines where, on account of physical conditions, comparatively light wheel loads must be carried. The largest of these engines can be safely used on rails weighing 70lbs. per yard, on the assumption that each 10lbs. per yard of rail, properly supported by cross-ties, can sustain a load per wheel of approximately 3,000lbs. Four types are represented, viz.: The 4-4-0, suitable for passenger service; the 2-6-0, specially fitted for freight service; the 4-6-0, which can be adapted to either passenger or freight service, and the Consolidation (2-8-0), which, with a large amount of weight on driving wheels, is suitable for heavy freight service. While these types have, during recent years, been largely superseded in trunk line service by locomotives of greater capacity, they are usually quite adequate for work on short roads and branch lines.

BOOK REVIEWS.

The Fan, including the Theory and Practice of Centrifugal and Axial Fans. By Chas. H. Innes, M.A. Revised by W. M. Wallace, Wh.Sc., Assoc.M.Inst.C.E., and F. R. Jolley, M.Sc. Second edition. London: Technical Publishing Company. 7½in. by 5¼in. 302 pp. Price 8s. 6d. net.

The excellence of this text-book was impressed upon us when it made its first appearance, and a lengthened acquaintance has confirmed our first impressions. The author's treatment of the subject differed from the accepted theories that had been current, and we think it is now generally admitted that the theory of the conservation of energy is a more rational starting point, and gives results more closely agreeing with experiments than the theory usually adopted. The book is one intended to meet the wants of designers, and contains pretty near all the reliable information available on the subject. The death of the author has necessitated the work of revision being undertaken by others, but, as far as we have been able to check it, it has been well done, and we have every confidence in recommending the book.

* * *

The Principles of Electrical Engineering and their Application. By Gisbert Kapp, M.Inst.C.E., Professor of Electrical Engineering in the University of Birmingham, Past-President Institution of Electrical Engineers. Vol. 1: Principles. London: Edward Arnold. 9in. by 6¼in. 354 pp. Price 15s. net.

The author needs no introduction to the electrical world, and his past contributions to engineering literature are a guarantee of the thoroughness of anything from his pen. In the present volume, he seeks not so much to cater for the electrical specialist as the general engineer who desires a sound grasp of fundamental principles and of their application to practical engineering without being burdened with minute details but who occasionally is interested in the question whether and how any piece of electrical plant can be adapted to a particular purpose. The merit of the book lies not in its presentation of any new facts or theories, but in its treatment of existing ones, the aim being to make it a text-book for all engineering students and a handbook for the general engineer. This latter term, implying one who has received a sound training, and is fairly familiar with the calculus.

* * *

English and American Tool Builders. By Joseph W. Roe, Assistant Professor of Machine Design Sheffield Scientific School, Yale University. Yale University Press. 9½in. by 6½in. 315 pp.; or Oxford University Press. Price 12s. 6d. net.

Probably at no previous period has the importance of machine tools been more strongly impressed on engineers than the present, when the destinies of nations may be said to depend almost entirely upon them. As the war progresses it is resolving itself more and more into a contest between mechanical engineers, whose pre-eminence is measured by their ability to design and construct the tools for the manufacture of munitions and armaments. Of the great designers of machine tools little is known by the general public. Their work is too technical for its value to be understood except by engineers who depend on their products, and only a minority even amongst the latter fully appreciate the influence exerted by machine tools on the accuracy and rapidity of production, which is such a distinguishing feature of mechanical engineering workshops at the present day. The names of soldiers, sailors, statesmen, and authors are written large on the pages of history; but it requires a great deal of search to discover those who invented the machine tools which have so largely contributed to the engineering progress that has marked the last century. Their works live after them, but what manner of men they were, what lives they led, and what were the circumstances that led to their discoveries and improvements are matters on which the intelligent enquirer is, owing to the paucity and scattered nature of the information available, largely baffled. For this reason we welcome the work before us, and its issue at the present juncture, when the subject

of machine tools bulks so largely, is timely. It is curious to note in following the development of machine tools how exclusively it is connected with British and American engineering. Other countries have contributed in some degree, and the French and Swiss and Germans have been pioneers in many mechanical improvements; but practically all the creative pioneer work in tool design and building, especially those used in connection with what may be termed heavy engineering, has been done here and in America. In the lives of the chief characters who have mainly contributed to this end the author has found ample material for a treatise which is not only interesting but instructive.

* * *

Dynamo and Motor Attendants and their Machines. By Frank Broadbent, M.I.E.E. Eighth edition. London: S. Rentell and Co., Ltd. 7½in. by 5¼in. 212 pp. Price 2s. 6d. net.

This is a useful and instructive book with a deservedly wide circle of readers; but the matter, which is copious and good, is presented in anything but an attractive manner, and we are sorry efforts have not been made in issuing this edition to use larger and better displayed type. There is a monotonous appearance about the pages that is repellent. This criticism may seem rather carping, but it really is not so, for the value of a book of this kind intended for constant and handy reference is largely increased by the rapidity with which reference may be made. Just as a good picture deserves a good frame, so a good book—and this is one apart from these blemishes—deserves a little taste in the presentation of its matter to readers, and we trust our hints will be taken note of when the next edition is prepared.

* * *

Engineering Applications of Higher Mathematics. By V. Karapetoff. Parts II., III., IV., V., dealing respectively with Problems in Hydraulics, Thermodynamics, Mechanics of Materials, and Electrical Engineering. New York: Wiley & Sons. London: Chapman & Hall. 8¼in. by 5½in. 100 pp. Price 3s. net each volume.

The practical application of the calculus is often a trouble to engineers, even when they have undergone a course of pure training in the higher mathematics, if circumstances do not for a few years require its practice, and sometimes even without this handicap, owing to lack of confidence in it as a tool, or unfamiliarity with the analytical methods of approaching a particular problem. These books in this respect supply a distinct want, and the division of the engineering field into sections enables the reader to select the one in which he happens to be most interested. The books are clearly printed, and the author's methods and explanations as simple as the matters dealt with will allow. We have pleasure in recommending the books to students and also to older engineers who have left their student days behind, and occasionally want to rub up mathematics which have got rusty from lack of exercise.

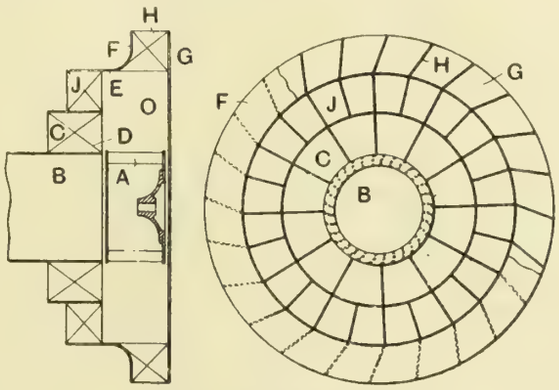
* * *

Aeronautical Engines: A Critical Survey of Current Practice, with Special Reference to the Balancing of Inertia Forces. By Francis J. Kean, B.Sc. 31 plates; 78 illustrations. London: E. and F. N. Spon. 9in. by 5½in. 94 pp. Price 6s. net.

This is essentially a book for the designer of high-speed engines for aeronautical work whose lightness and high power are so extremely important. The class for whom it is written is eminently select, but they cannot well afford to be without it if they wish to acquire easily a sound knowledge of the intricate problems associated with the correct balancing of the moving parts, which is one of the most serious of the many difficult questions concerned in the evolution of an engine suitable for air craft. The author's treatment of the subject as regards text is very brief but clear, and little description is expended on details outside of the scope of the title. His main work is devoted to a series of large-sized diagrams, illustrating the resolution and composition of the forces arising out of moving parts of the engine and the methods of balancing them, and draughtsmen engaged in this highly specialised branch of engineering will be grateful for the hints on design here presented and evidently gleaned from an intimate knowledge of his subject.

DAVIDSON'S CENTRIFUGAL FAN.

THE accompanying illustrations show a design of centrifugal fan of the induction type, wherein the primary and induced fluids are either both gases or both liquids, and where the object is to combine the volume of the primary and induced flow, and discharge the same as a whole from the apparatus. The fan, which is the invention of Mr. S. C. Davidson, Sirocco Engineering Works, Belfast, is shown in Fig. 1, and is provided with two concentric annular induction inlets. There is combined with a fan wheel A of the drum shape an inner or main duct B leading up to and terminating close to the intake end of the fan wheel, the inner duct being of about the same diameter as the outer circumference of the fan wheel. Outside the inner duct and concentric therewith is an intermediate induction duct C, which terminates in an axial direction at or about the plane of the intake end of the fan wheel. The inner duct and the intermediate duct C is provided with axially-disposed guide plates D, disposed radially to prevent the circumferential rotation of air in the induction duct C. Beyond the induction duct C is another or outer induction duct J, the casing E of which is also carried in an axial direction over the plane of the intake end of the fan wheel for a suitable distance as shown. At its termination the casing of the duct J is connected to an annular plate F parallel with the plane of rotation of the fan wheel as shown. The annular plate F together with a back plate G, which extends radially and parallel with the back of the fan wheel, forms a circular casing for a peripheral opening of suitable width, from which the whole volume of air both from the fan wheel and from the inner and outer induction ducts can freely discharge, and



DAVIDSON'S CENTRIFUGAL FAN.

to render the discharge more positive a series of stationary guide plates H are mounted in or around the periphery of the circular discharge.

In operation when the fan wheel A is being rotated the air will pass by the main inlet B into the fan wheel, and will be discharged therefrom into the space O, and an induced flow of air will flow inward through the induction ducts C and J, and will pass transversely or in an axial direction into the air which is being discharged directly from the fan wheel. The guide plates H prevent circumferential rotation of the air in the induction ducts. The inner induction duct C terminates in an axial direction at or about the plane in which the rear edge of the periphery of the fan wheel revolves, whereby the peripheral annular space which is closely adjacent to and immediately surrounds the periphery of the fan wheel is so far free from obstruction that under the influence of the incoming induced flow of air through the ducts C and J the fan wheel, when of the multi-bladed drum shape with long axially and relatively narrow blades of the type shown, may become effective for the discharge of air through the whole or practically the whole of its axial length instead of being partly negative and partly positive. With a fan of the construction described the total volume of air moved and dealt with is so much greater than the volume which actually passes through the fan wheel itself that a relatively small fan can be employed for the volume to be dealt with.

THE USE OF POWDERED COAL IN METALLURGICAL PROCESSES.*

BY C. J. GADD.†

(*Concluded from p. 260.*)

Furnaces.—In the metallurgical processes powdered coal has been applied with commercial success to various types of furnaces, such as annealing, puddling, heating, open-hearth, ore nodulising, &c. In order to ensure success in applying powdered coal to furnaces, no matter what their type may be, one general rule must

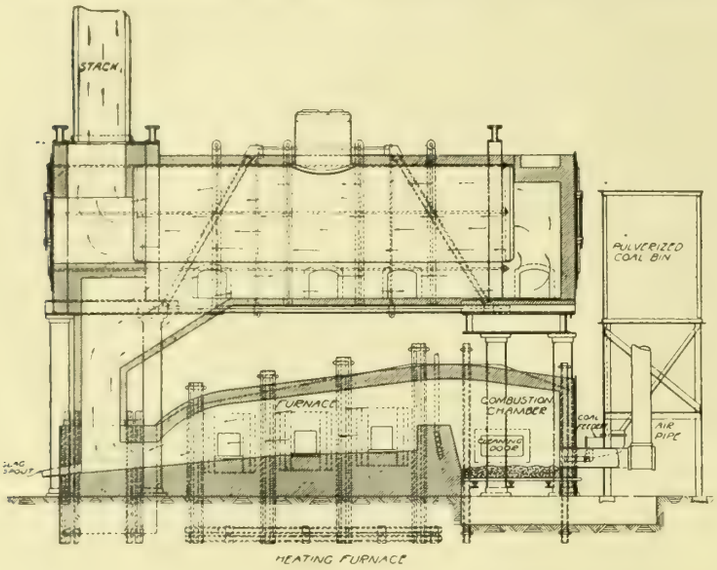


FIG. 9.

be obeyed: namely, that it be fed to the furnace at a uniform rate in a thoroughly atomised state, and that the furnace be so designed that complete combustion may take place while the coal is in suspension.

Fig. 9 shows a sectional elevation of a 3-door heating furnace of the type generally used in heating iron piles and steel billets, arranged with a waste-heat boiler and equipped for burning powdered coal. In this installation a low-pressure burner discharges the mixture of coal and air into a combustion chamber. As the fuel combusts the heat thus produced is conveyed over the furnace hearth, and the waste gases pass through the boiler setting to the stack. Loose grate bars supporting a bed of about 9in. of ash form the combustion chamber hearth, and a large portion of the ash contained in the coal collects over this surface. After each heat the accumulation of ash is raked out through the cleaning doors, and once a week the grate bars are dropped and the chamber thoroughly cleaned. The accumulation of slag at the base of the uptake flue is tapped out from the slag runner. The ash which falls upon the material in the furnace is too small a proportion to cause any ill effect. In the boiler settings and flues considerable ash is deposited in the form of an impalpable powder, which is cleaned out once every 12 hours.

As to the economy of fuel on puddling furnaces, the use of powdered coal has shown an average saving of about 30 per cent. to 36 per cent., and on heating furnaces 15 per cent. to 25 per cent. For every pound of coal fired the waste-heat boilers show an evaporation of from 7lbs. to 8lbs. of water.

The use of powdered coal as a fuel in soaking pits represents probably the latest application of this form of fuel in the metallurgical arts. Fig. 10 shows a sectional elevation through a soaking pit equipped for burning this form of fuel. The drawing clearly shows the construction, and the mode of operation will be readily understood. Five double soaking pits of the general design shown are now in operation and are giving very satisfactory results.

At the present time four different steel plants are using this form of fuel in open-hearth furnaces with encouraging results. While all the installations are more or less in an experimental stage and not as yet fully developed, owing to the limited time of application, the results obtained thus far have fully demonstrated the economy of powdered coal over oil and show equal economies with producer gas.

Fig. 11 shows the four different methods at present employed for applying powdered coal to open-hearth furnaces. A, B, and C represent installations in which high-pressure siphon type burners are used, similar to those shown in Figs. 5, 6, and 7. One burner is placed on each end of the furnace, the fuel being reversed as in the case of producer gas. As the gas flues are eliminated in this process, the regenerative chambers in most cases have been enlarged, and in place of checkers staggered arches or parallel walls have been built to give the necessary regenerative area. There are at the present time one 75-ton, three 60-ton, and four 35-ton open-hearth furnaces of the regenerative type in operation with modifications in the constructon of the regenerative chambers as described. At one plant the results obtained have been so encouraging that a second furnace of 75 tons capacity is now under construction.

D represents a somewhat radical departure from the old-time theories of open-hearth furnace practice. By reference to the diagram it will be noted that the burners are arranged only at one end of the furnace, the path of the flame being always in one direction. There are no regenerative chambers, air at room temperature being used for combustion of the fuel. The theory underlying this method of applying powdered coal to open-hearth furnaces is: (1) The fuel is burned above the bath, and all the heat contained in the coal is instantly developed in the furnace. (2) As the path of the flame is in one direction, all parts of the furnace are maintained at the same temperature. (3) By reason of their high radiating capacity, the infinite number of minute incandescent particles in the powdered coal communicate the heat by radiation, and not by convection, thus eliminating the necessity of bringing the surrounding air to the temperature of the coal particles. (4) All the heat in the waste gases is conserved and used in the production of steam.

The extra fuel consumed, due to the use of cold air, is offset: (1) By the elimination of all loss in the gas producer process. (2) By the elimination of all loss due to frequent reversals. (3) By the elimination of all loss in waste heat taken up by the

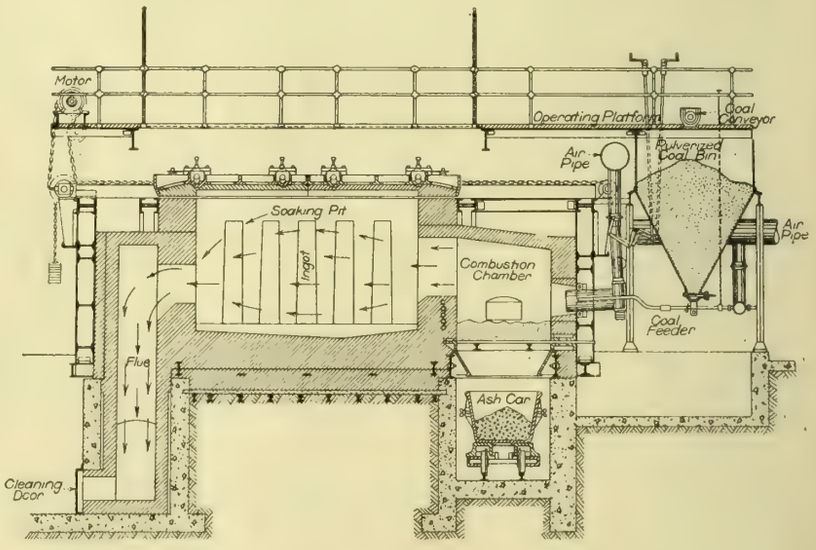


FIG. 10.—SOAKING PIT.

regenerative chambers. (4) By the elimination of the expensive maintenance cost of producer plant and regenerative chambers. (5) By the greatly reduced first cost of installation.

Fig. 12 shows a sectional elevation of this furnace. A section through the combustion chamber looking towards the back wall is shown in the upper left-hand corner. By reference to this view it will be noted that three burners are employed—the central one of the high-pressure siphon type shown in Fig. 8, the two side ones of the low-pressure type shown in Fig. 4.

As powdered coal requires a high temperature for ignition and maintained combustion, there would be no incentive for the powdered fuel to ignite in the cold furnace after charging, espe-

* Paper read at a meeting of the Mining and Metallurgical section of the Franklin Institute, April 6th, 1916.

† Chief Engineer, American Iron and Steel Manufacturing Company, Lebanon, Pa.

cially since the air necessary to support combustion is also cold. The combustion chamber in this installation is maintained at a high uniform temperature at all times by the two low pressure burners. The high temperature maintained in the combustion chamber preheats the air furnished to support combustion, and,

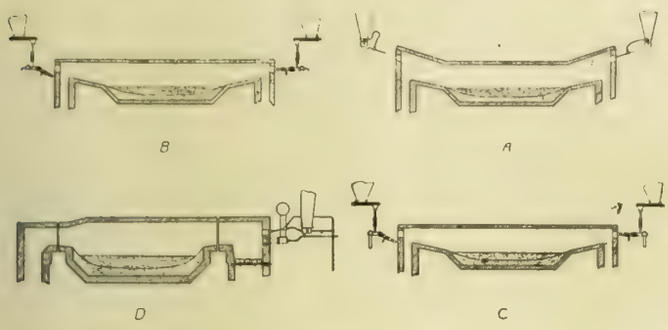


FIG. 11.

as the high-pressure siphon burner discharges the powdered coal through the hot zone of the chamber, complete combustion of the fuel is ensured. Auxiliary air for combustion is admitted through the back wall of the combustion chamber at the roof line. The accumulation of ash in the combustion chamber is raked out through the cleaning doors after every heat and is discharged through a trap door in the charging floor into the ash car below.

From a metallurgical standpoint, the deposit of ash on the bath is too small an amount to be noticeable. In the slag pocket at the bottom of the vertical flue the ash and the brick slag form a thick, pasty mass, the tough consistency of which makes its removal difficult. Beyond this point the ash settles in the flues as an impalpable powder. After each heat it is stirred up by inserting a compressed-air jet through the separate cleaning doors of the flues. The ash clouds thus produced are picked up by the flue draught and are carried in suspension out of the stack. The boiler tubes are cleaned with steam blowers four times each day. The course of the waste gas is indicated by the arrow marks, and is shown discharging into the flue connecting with the waste-heat boilers.

Fig. 13 shows a plan and elevation of the waste-heat plant, also a sectional elevation through the boilers and economisers. The course of the waste gases can be followed by the arrow marks,

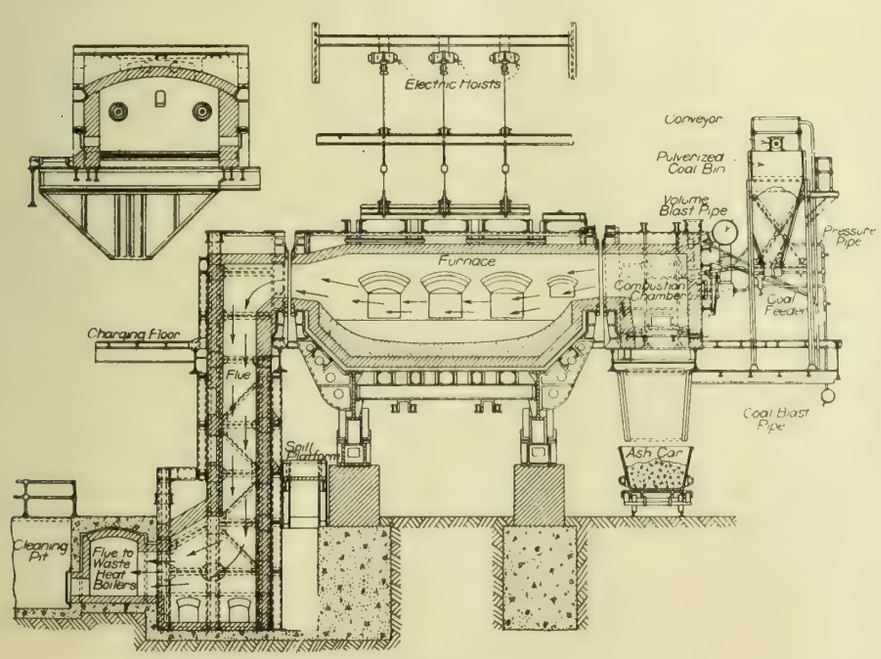


FIG. 12.

and the general operation will readily be understood by reference to the drawing. It will be noted that by the arrangement of the flues and dampers the whole waste-heat plant may be by-passed. The economiser and both boilers may be by-passed either separately or in combination, as desired. The flexibility of this arrangement permits any adjustment or repairs to the boilers or economisers without affecting the operation of the furnace.

Within the past few months four 50-ton basic open hearth furnaces thus arranged have been placed in operation. In this short period operating conditions have demonstrated the soundness of both the underlying theory and the engineering principles involved in this method. Compared with producer gas, equally high temperature is attained. Uniform temperatures throughout

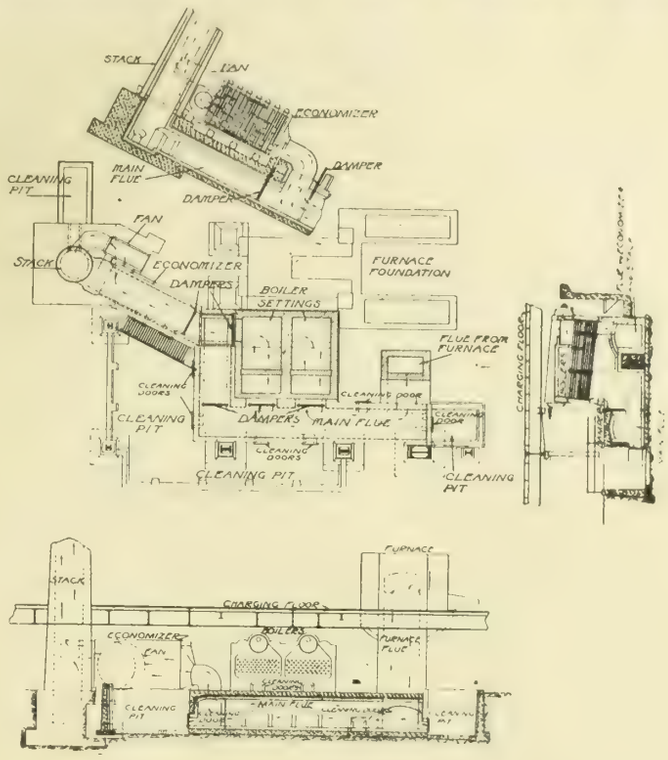


FIG. 13.

the furnace are maintained. Heats can be made within reasonable time. Fuel consumption is high. This, however, is offset by the fact that the waste-heat plant produces an average evaporation of $6\frac{1}{4}$ lbs. of water per pound of coal fired in the furnace. Compared with the best boiler-room practice, $62\frac{1}{2}$ per cent. of the fuel consumed by the furnace is used in the generation of steam, leaving $37\frac{1}{2}$ per cent. chargeable to steel production. Based on this reasoning, economies over oil and producer gas are fully substantiated.

In the use of powdered coal in metallurgical furnaces we have arrived at a stage of development where fixed rules may be laid down for its application which, if strictly followed, will result in high economy and efficiency. The personal equation is the important factor in operating part of the apparatus as developed thus far. It is necessary to depend too greatly upon this uncertain element.

In the drying process the operator may at any moment upset the complete equilibrium of a plant either by overheating the coal or by not drying it enough. In the furnace operation three or four separate adjustments are required, depending on the burner used, each adjustment bearing a fixed relation to the others. These adjustments are: The control of the coal feed, the control of the cold blast, the control of the volume blast, and the control of the furnace draught, where mechanically operated low-pressure feeders and burners are employed, all of which controls are separately left to the judgment of the operator. When we consider that there is no fuel so sensitive to correct application as powdered coal, and when we realise the exact precision required in its manipulation, the dependence placed on the personal element is at once apparent.

In order to obtain uniform conditions, it is necessary to eliminate the personal equation as far as possible. In the drying

process this might be accomplished by an automatic control of the coal feed governed by the temperature of the dryer cylinder. In the case of the burners and feeders this might be done by a single adjustment regulating and supplying the correct proportion of air and coal, with provision for adjusting the air and coal independently in order to obtain correct proportions for different grades of fuel, thus producing an absolutely uniform combustible mixture, which will be maintained, regardless of the quantity supplied, after once setting the adjustment.

The high economy and efficiency of powdered coal in the metallurgical processes, under the limited application of this fuel and the limited development of apparatus, provide an index of its possibilities under more general use. With a further development of apparatus this form of fuel doubtless will eventually supplant oil, tar, and producer gas in the varied fields where they now hold supremacy.

FUEL ECONOMY ON THE NORTH-EAST COAST AS A RESULT OF ELECTRIC POWER SUPPLY.*

BY R. P. SLOAN.

ELECTRIC power supply, though of comparatively recent development, has already had a marked effect upon the industries of the North-east Coast, for example :—

1. A great saving of coal and reduction of smoke has resulted. There is now, apart from the power companies, practically speaking, no coal burned on the Tyne for power purposes, except by the railways and chemical factories and some collieries. The Tyne shipyards and engineering works may be said to have adopted electricity to the exclusion of all other forms of motive power.

2. The application of electricity to all new uses has been facilitated :—

(*a*) Many collieries depend entirely upon electricity supplied from the Newcastle and Durham electric power companies' combined system for all their power requirements.

(*b*) As a result of the adoption of electric traction, the suburban railway traffic facilities of Newcastle are more ample than those of any other town of similar size.

(*c*) Electricity has been applied to freight haulage on the Newport-Shildon line (and this is the first real example of heavy freight haulage by electric locomotives in this country).

(*d*) Electricity has been applied with particular success to drive rolling mills and colliery winders, and for other purposes requiring the concentration of a large amount of power on one shaft.

3. New industries have been established in the district purely because of the cheap power available.

4. Extensive utilisation has been made of the waste heat and gases existing in the area for the production of electrical energy. In this regard the district occupies a unique position owing to the extent to which its power requirements have been met by electricity produced as a by-product of two of its largest industries—the making of pig iron and the making of coke.

5. Several small, and therefore uneconomical, generating stations—municipal and company—have been shut down, and the electrical distribution systems which they supplied have been connected up to the power supply companies' system.

The problem of power supply in any district is so completely governed by local conditions that it may be permitted at the outset to summarise the nature and extent of the staple industries of the North-east Coast. The table above does this in convenient form.

It will be seen that in coal, iron and shipbuilding the North-east Coast figures represent respectively and approximately one-fifth, one-third, and one-half of the nation's output. It was early realised that the more completely the electrical wants of the whole community could be met, the more cheaply could a supply of electricity be given and the more stable would the electric supply industry become. Our engineers therefore proceeded to design the system so as to be capable of producing current at a minimum cost and of providing a satisfactory supply for all purposes—power, traction, lighting, and electro-chemical and similar processes.

The extent of the area (1,400 sq. miles) necessitated the generation of electricity at a pressure and in a form facilitating transmission over long distances, while the nature of the market to be catered for made it essential that the current should be produced as cheaply as possible. This, in turn, involved the use of extensive sites with ample coal and water facilities for the main coal-fired power stations, which were erected to deal with such portions of the load as could not be supplied with electrical energy generated by waste heat. From the two main stations situated on the River Tyne the transmission and distribution networks extend into and through the city of Newcastle-upon-Tyne, northwards to Blyth and beyond, and eastwards along the River Tyne, through Wallsend to North Shields. On the south bank of the Tyne the system extends southwards through the county of Durham from the coast to Consett and Bishop Auckland on the west, and then joins up with the system of the Cleveland and Durham Electric Power Company, whose area covers the South Durham and Yorkshire districts, including the Cleveland mining district, Stockton-on-Tees, Middlesbrough, &c. The distance between the northern and southern extremities of the transmission system is 70 miles, and it is now possible to obtain electricity on the same system as regards frequency and voltage throughout practically the whole of the area embraced in the scheme. The main transmission and distribution system is a 3-phase system with a frequency of 40 cycles per second, and the working pressure is 20,000 volts.

The capacity of plant installed represents about one-ninth of the total plant installed in public supply stations in the United Kingdom, but as the North-east Coast power companies are working at a more constant load—*i.e.*, a better "load factor"—the electricity actually generated is about one-fifth. The total horse-power at present being supplied is 343,000 h.p.

North-east Coast Industries.

	Population at Census, 1911.	Coal mined, 1913.	Coke made, 1913.	Ironstone mined, 1913.	Pig iron made, 1913.	Merchant shipping built, 1913.
		Tons.	Tons.	Tons.	Tons.	Net tonnage.
North-east Coast industrial area	2,300,000	56,352,218	7,500,000	6,010,836	3,869,214	625,289
United Kingdom	45,211,888	287,430,473	20,529,732	15,997,328	10,260,315	1,231,921
Ratio— North-east Coast / United Kingdom	Per cent. 5·1	Per cent. 19·6	Per cent. 36·5	Per cent. 37·5	Per cent. 37·7	Per cent. 51·0

Though the extension of the power supply system has been rapid, its development and the growth of its profit-earning capacity were considerably delayed by the work which had to be done from time to time, and the sacrifices that had to be made, to secure uniformity of system. Unfortunately with each amalgamation, or extension of area, considerable alterations had to be effected in the system of the new undertaking concerned. For example, the system of the Newcastle-upon-Tyne Electric Supply Company—the pioneer company—the first instalment of which was laid down in 1899, is a 3-phase 40-cycle system. That of the Durham Collieries Electric Power Company, the operation of which the Newcastle-upon-Tyne Electric Supply Company took over in 1907, was a 50-cycle 3-phase system, while the Tees area of the Cleveland and Durham Electric Power Company, where supply was begun in January, 1906, was originally designed for 25 cycles. The same company's Consett and Bishop Auckland stations were designed, one to give 3-phase 25-cycle current, the other 2-phase 50-cycle current. It will be appreciated that these alterations (involving in some cases the complete redesign of system) have necessarily delayed development, but it was considered best to secure uniformity, even at some sacrifice of time and money. All these other systems were sanctioned and commenced some time after the original Newcastle system was laid down.

The work of making the systems uniform has been completed, and, in addition, several small and therefore uneconomical generating stations have been shut down. Throughout the area embraced in the scheme there are now only three public supply

* Paper read before joint meetings of Sections B and G of the British Association at Newcastle, Sept. 8th, 1916.

stations not conforming to the standard system and frequency, viz., those of the Sunderland, South Shields, and Darlington Corporations.

The local conditions governing power supply in the district are: (1) The low price of coal, which would enable the manufacturers to produce power themselves at relatively low rates. (2) The fact that the manufacturers' works are mostly of considerable size, *i.e.*, their individual electrical requirements are large. (A factor invariably of vital importance in the production of cheap current, whether by a public company or a municipality or by a private manufacturer, is the capital expenditure per useful horse-power of plant. This decreases as the size of plant grows, while the running efficiency at the same time increases.) (3) The existence of large quantities of potential energy in the form of waste heat and combustible gas.

The first and second conditions have been met by the power companies, in erecting their main generating stations: (*a*) By taking full advantage of the best coal and water facilities available; (*b*) by installing plant of a capacity much in excess of that which any individual manufacturer, however large, could adopt; (*c*) by catering for all classes of consumers, thereby securing a diversity of load with a resulting constancy of output and so utilising the plant installed to the best possible advantage. These factors, combined with the employment of a highly-skilled technical staff and attention to numberless relatively minor details, have resulted in securing an efficiency of production much greater than that practicable to any manufacturer producing power merely as an auxiliary to his main business. This is, after all, an age of specialisation, and the production of electricity from coal at a minimum of cost presents opportunities for the highest technical skill and for unremitting vigilance.

Power supply in this district began on the north bank of the Tyne. It is natural, therefore, that its highest development was reached there earlier than in other parts of the district. By 1908 it could be said that there was not a single firm of shipbuilders or engineers on the north bank of the Tyne which did not take 95 per cent. of its power from the company. To-day the proportion is probably higher still. Even taking the whole area, it may now be said that, as regards the engineering trades as distinct from collieries and iron and steel works, from 75 to 80 per cent. of the power is supplied from the power companies' system.

The credit of electrifying the Newcastle suburban railways is, of course, due to the enterprise of the North-eastern Railway Company; but the fact that they were the first important English railway to electrify a portion of their system, and that they purchased the necessary electricity from the Power Company, shows that the availability of cheap power is an advantage not only to manufacturers but to the public generally in facilitating the introduction of electric traction. Since the electrification of the Newcastle system the train service has been more than doubled and the schedule speed improved by 20 per cent. A comparison with other cities at home and abroad shows that no other town of similar population has so extensive an electrified railway system or so frequent a suburban service, and this has, of course, resulted in a large increase of travel.

The Newcastle and coast suburban railways were electrified more than 10 years ago. More recently the North-eastern Railway Company have applied electricity to a freight line, and have electrified some 50 miles of track on their Shildon-Newport route, which carries the heavy mineral traffic between the coalfields of South-west Durham and the blastfurnaces and ironworks of the Middlesbrough district. Few people realise that goods traffic forms the greater portion of the total business of the railways in this country, and is therefore of greater importance than the passenger traffic.

The electric locomotives, designed by Mr. Vincent Raven, the railway company's chief mechanical engineer, and built under his supervision at the railway company's works at Darlington, are each capable of hauling a load of 1,400 tons at a normal speed of 25 miles per hour on the level, and of starting a train of the same weight on a 1 in 300 gradient. No special generating station has been built, the whole of the current required being supplied by the power companies, whose existing mains are tapped at two points where they touch the railway.

The supply of electricity to coal mines—though the important colliery areas were not touched until some five years after power supply started on the Tyne—has now reached a high state of development. It is estimated that, apart from the smaller colliery supplies, pits having an output of over 20,000,000 tons of coal per annum now depend upon the power companies for their power supply. The uses to which electricity is put include pumping, hauling, ventilating, winding, &c., and, as elsewhere, the simplicity and general advantage of the electric motor over all other forms of engine has made itself apparent. It is estimated, in the case of collieries, that at least 75 per cent. of the coal previously used for power purposes has been saved as a result of burning it at the economical generating stations of the power companies instead of each pit generating its own power; this is equivalent to a saving of at least 1,000,000 tons of coal per annum, apart altogether from the saving of coal resulting from the utilisation of waste heat, discussed later, and the saving of coal used for producing power for shipbuilding and engineering works and for the railways.

One of the most interesting features of the problem that had to be dealt with, and which it is not too much to say is also of considerable national importance, was the utilisation of the waste heat in the district. The counties of Northumberland and Durham and the North Riding of Yorkshire produce some 7,500,000 tons of coke per annum. The bulk of this used to be made in the old-fashioned beehive ovens, but during the last decade the retort type of oven has made rapid progress on account of its increased coke yield and the value of the by-products recoverable. The waste heat from these ovens and from the blastfurnaces and the exhaust steam from blowing engines in the Cleveland district form a considerable source of power.

The problem of the utilisation of this waste heat has been solved by the establishment of local generating stations where such surplus power is available. These plants feed into the main power companies' system and the stations work in parallel with the five main generating stations of the power companies. These local generating stations, or "Waste Heat" stations as they are commonly called, are run so that they each supply the maximum amount of energy possible—depending on the supply of waste heat or steam available—all regulating being done by the main power stations.

The power company need install no spare plant in any of the waste-heat stations connected to its system, being able to meet any variation of load by means of its coal-fired stations, which also act as standby against any breakdown. Moreover, the power company, having a market for current many times greater than the output of any individual waste-heat station, is able to run such stations continuously at their maximum output capacity, so utilising completely all the current that can be produced therein; whereas it is impossible to conceive the power requirements of an individual coke-oven and colliery installation coinciding even approximately over 24 hours with the amount of gas or waste heat available.

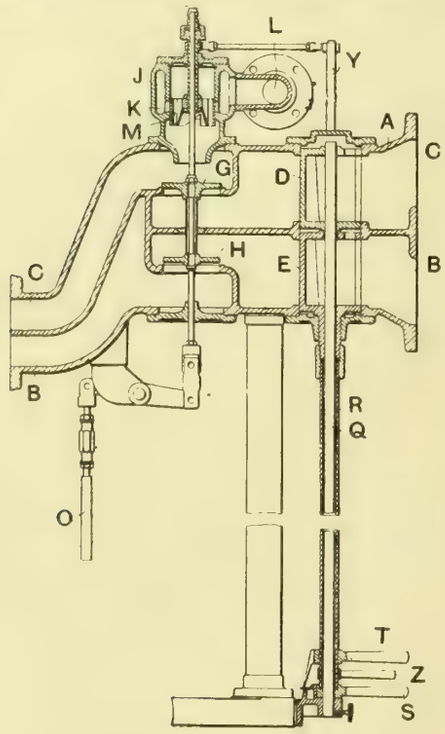
The first waste-heat station was erected in 1905 by the Priestman Power Company, a subsidiary company formed jointly by the Priestman Collieries, Ltd., and the Newcastle-on-Tyne Electric Supply Company, Ltd., at Blaydon, in conjunction with new coke ovens then being erected by the Priestman Collieries, Ltd., who were the first to see the advantages of co-operating with the power company.

There are now 11 waste-heat stations in operation in the North-east Coast area and, in a typical day's working of two such electrical generating stations the waste heat available is sufficient for the generation of an amount of power very considerably in excess of that required by the colliery owners. As a matter of fact, during the year 1915 these two stations alone turned out 40,000,000 units, of which only 10,000,000, or 25 per cent., were required for the working of the collieries, the remaining 30,000,000 units being delivered into the mains of the power supply company. The total coal saving due to utilisation of waste heat in the North-east Coast now amounts to some 150,000 tons per annum.

This brief account of what has already been done on the North-east Coast will show the great economy which has been effected. There can be no doubt that a proper appreciation of the enormous economies which may be effected by the avoidance of inefficient and wasteful separate power installations, and by the pooling, not only of all power requirements of all kinds, but also of all power-producing plants, into one interconnected power supply system in each industrial district, will be one of the most important factors in that general development of the country's industries which we are all hoping to see.

IMPROVEMENTS IN GAS ENGINES.

An arrangement has recently been designed and patented by the National Gas Engine Company, Ltd., Wellington Works, Ashton-under-Lyne, and Mr. S. Travis, to enable gas engines in which the compression of the mixed charge of fuel and air takes place in the engine cylinder to operate on gaseous fuel of a low calorific value as well as on gaseous fuel of a higher calorific value without structural alteration or alteration of the compression ratio or inlet valve adjustment. The arrangement, suitable for a single cylinder engine, is shown in the accompanying illustration. There is provided a valve box A having two conduits B and C formed in it, one B connected to an air-supply pipe and the other C to a branched pipe, one branch conveying producer gas and the other exhaust products, coming either from the engine in question or any other engine. Controlling cocks D and E are provided in each of the conduits of the valve box, and a switch cock is provided at the junctions of the branches of the pipe conveying producer gas and exhaust products to the conduit C. Valve seats are formed in the sides of the conduits of the valve box adapted to co-operate with the two



IMPROVEMENTS IN GAS ENGINES.

discs G and H of a double-beat valve. The conduits are continued through the valve box to the engine cylinder in such a manner as to convey the two working fluids to the engine cylinder on leaving the valve box. Coaxially with the seats formed in the valve box a cylinder J, having ports K in it, is provided, the ports communicating with a supply of coal gas by way of the conduit L. A piston M having inclined edges is provided adapted to slide in the cylinder, and more or less expose the ports K. The bottom of the cylinder J opens into the conduit C of the valve box, which conveys producer gas or exhaust products. The piston M is adapted to be reciprocated in the cylinder by an extension of the stem of the double-beat valve. The double-beat valve is controlled by a governor through an operating rod O. The piston M which controls the coal gas supply is so attached to the valve stem that the piston can be rotated relatively to the cylinder wall so as to provide an adjustment in consequence of the inclined edges of the piston. The adjusting cocks D, E, in the two conduits of the valve box are situated one above the other coaxially so that their controlling spindles Q and R are coaxial. These spindles carry adjusting handles S and T moving over graduated sectors supported on a bracket below the valve box. By a suitable linkage and a spindle Y the angular position of the coal gas controlling piston M may be controlled from a handle Z situated in proximity to the other controlling handles.

In operation, supposing that the engine is running on producer gas, the desired mixture is obtained by setting the cocks D, E, in the valve box conduits, and the speed of the engine is controlled by the double beat valve G, H. It will be understood that the supply of coal gas by way of the conduit L is shut off and the switch cock in the pipe leading to conduit C is set to pass producer gas. When it is desired to run on coal gas the switch cock is set to pass exhaust products to the conduit C, and the supply of coal gas by way of conduit L is turned on. It is then easy to adjust by means of the handles T, Z, and S the mixture of air, coal gas, and exhaust products to obtain a mixture having approximately the same calorific value as the mixture previously used of air and producer gas. The valve box A may be so arranged that the various fluids on leaving the double beat and piston valves divide into two or more streams to feed any desired number of cylinders. In the case of a four-crank-tandem engine, a double set of gas and air connections may be provided. In the case of two or three-crank-tandem engines a single set of valves may be employed.

THE PRINCIPLE OF SIMILITUDE IN ENGINEERING DESIGN.*

BY T. E. STANTON.

In preparing the present paper, which, at the suggestion of the Committee of Section G, has for its subject the Principle of Similitude, it seemed to the writer that it would be meeting the wishes of the majority of the audience if the paper were mainly devoted to illustrations of the usefulness of the principle in solving practical engineering problems rather than to any formal demonstration of it, for which reference may be made to the literature of the subject. As a broad definition it may be said that the principle of similitude is the principle according to which a representation of any particular mechanical phenomenon can be made so that the magnitudes of all characteristics of the same kind are changed in the same ratio, or, in other words, there is a definite change of scale for each characteristic. Of course, since each characteristic can be expressed in terms of the fundamental units such as those of mass, length, and time, it is ultimately only the scales of these units which are altered, and it follows from the principle that these scales cannot in general be changed arbitrarily, but only according to a definite relation determined by the principle. Now, there is one case of such representation which is familiar to every engineer, and that is when the only characteristic which is changed is the linear dimension. This case includes the whole subject of scale drawings of machines and structures and the construction of models, and the study of it forms an important part of the education of every engineer. Apart from this particular application, it can be assumed that, as far as the problems of the engineer are concerned, the application of the principle of similitude means in nine cases out of ten nothing more than the laying down of the conditions of an experiment on a small-scale model of any mechanical arrangement which we wish to design, so that we can predict with accuracy any particular characteristic of it from an observation of the corresponding characteristic of the model.

The first practical application of the principle to an engineering problem was, I believe, Mr. William Froude's method, proposed in 1870, and carried out in the following years, of obtaining the "wave-making" resistance of a ship from an experiment on a small-scale model of it towed in water. A general demonstration of the conditions for similarity of motion in water flowing through orifices under gravity, to which Mr. Froude's problem is analogous, was given in a paper read before this association at the Glasgow meeting just 40 years ago by Prof. James Thomson. In this paper it was proved from dynamical considerations that in the flow of water relative to similar and similarly situated orifices similarity of motion in corresponding stream-lines would only take place if the linear dimensions of the orifices were proportional to the squares of the corresponding velocities of flow, and that when this condition was fulfilled the discharge would be strictly proportional to the $\frac{5}{2}$ power of the linear dimensions of the orifices or weirs. James Thomson's method of demonstration was, however, some-

* Paper read before Section G of the British Association at Newcastle-on-Tyne, September 7th, 1916.

what complicated for general application, and others have since been developed, of which the simplest and most readily applied is probably the well-known one due to Lord Rayleigh.

Another method and illustrations of its application to several of the problems discussed in the present paper has recently been given by Mr. Edgar Buckingham in a paper on "Model Experiments" read before the American Society of Mechanical Engineers in 1915. The method now adopted is to write down a list of all the variable characteristics which can affect the value of the particular characteristics which we wish to determine, and applying the principle of similitude we obtain a relation which must exist between certain other characteristics in the model and the full-sized test in order that the observed value of the particular characteristic for the model may be comparable (*i.e.*, in a known ratio) to the corresponding one in the full-sized test. This qualifying relation is called the Law of Comparison.

It would appear, therefore, that the use of the principle of similitude by engineers is essentially a modern device, for if one glances back over the history of the design of structures from the earliest times, we shall, I think, find no definite evidence that small-scale experiments were made use of for the purpose of design up till, say, 50 years ago. The principles according to which the proportions of the great works of architecture of past ages were evolved have always proved a fascinating subject of study, although in the opinion of our architectural friends it is one upon which no engineer should have the presumption to offer an opinion. If these proportions were entirely settled by æsthetic considerations this attitude might be accepted by engineers, but it is obvious that in some of the mediæval works considerations of equilibrium and of the strength of materials are of first-rate importance, and it is with such cases that the engineer is concerned. As regards the methods of design, it was the opinion of the late Prof. Rankine that the great works of antiquity evinced a profound study of the principles of equilibrium. This statement will, I think, be generally accepted if one interpret it as meaning that the study consisted of close attention to the behaviour under natural forces of such combinations of masonry as the æsthetic instincts of the designers suggested.

Again, of the testing of materials as we understand it, presumably nothing was known in mediæval times, but we may be certain that the early designers had a good working knowledge of the limiting stresses of their materials which was the result of accumulated experience of past failures of full-sized structures. I am informed by an authority on the subject that in the Gothic cathedrals of England the way can be distinctly traced in which during some hundreds of years successive designs were æsthetically improved by continuous refining in lightness of construction until a stage is reached when it would seem that the necessary courage to carry out the design failed the constructors. Doubtless there would be cases also in which the necessary courage to build was found and it was the structure which failed, but unfortunately these episodes are apt to be left unrecorded. In short, improvement in constructional design in past ages would appear to have been almost entirely due to an application of what in later days has come to be known as "The Squeers Method," but with this limitation, that the observations were all made on the full-sized structure.

I think, therefore, one may fairly conclude that scale-model testing is essentially a modern invention. It would not, however, be fair to the early pioneers in this subject to attribute the neglect of an appreciation of the information given by a scale-model test to a failure to realise its merits. Their problems nearly always dealt with the behaviour of structures which, when they failed, failed under their own weight, and not under the action of external forces, and in such cases, as we know, the force of gravity varies as the cube of the linear dimensions and the area of support as the square. It follows that a small-scale model of a structure, when made of the same material as the structure, is essentially stronger under its own weight than the structure itself, so that without the knowledge of the ultimate strength of materials which we now possess, a scale-model test would be worthless. Possibly it was this inherited and acquired knowledge of the futility of any small-scale model test applied to structures under gravity that was accountable for the general reluctance, amongst naval architects, to accept Mr. William Froude's suggestions of predicting the wave-making resistance of a ship from an experiment on a small-scale model of it towed in water at such a speed that the wave patterns produced by the ship and model were geometrically similar, the law of comparison being

$$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2}$$

under which conditions the ratio of the resistances would be

$$\frac{R_1}{R_2} = \frac{\rho_1\,l_1^3}{\rho_2\,l_2^3}$$

where l, ρ, and v are the linear dimensions, density, and velocity of the fluid respectively (case 5 of table appended). Fortunately Mr. Froude had the support of the Board of Admiralty at the time, and was enabled to carry out his proposed experiments, with the result, as we all know, that his method of small-scale model tests is now universally adopted as the only reliable method of the determination of the resistance of a ship of given proportions, except, of course, the heroic one of testing the full-sized ship. This, I believe, was the first application of the principle of similitude to the purpose of obtaining the data for the design of structures. No further extension of its use has taken place until comparatively recently, when it has been realised that it could also be employed to obtain some of the necessary data required in the design of aircraft, although in this case, as we shall see later, there is a practical limitation which does not trouble the designer of ships.

From this glance at the extent to which the principle of similitude is used by designers of structures, the conclusion may follow that the sole value of small-scale model experiments is for the determination of the fluid resistances of bodies moving in air or water. Admitting that these applications of the method are the most important, it by no means follows that they are the only useful ones. For example, although the use of tests of small-scale models of statically loaded structures and their details has not hitherto formed part of the routine in laboratories for testing materials, it is probable that, in many cases, such tests would give more valuable and more reliable results than the attempts we often see to apply the simplified elastic theory to problems for which it was never intended. Thus, in calculations on the stress distribution in beams, we are accustomed to make certain assumptions as to the manner in which the elastic deformation takes place, which enable us to apply the mathematical theory of elasticity and obtain results without the expenditure of great labour. In the majority of cases these results are sufficiently accurate for our purpose, but one is continually coming across cases in which they may lead to quite incorrect conclusions. The writer has often been impressed by the apparent horror with which the rigid elastician is accustomed to regard the recklessness with which the engineer will attack some extremely complicated case of stress distribution by means of the simple beam formula. In such cases it will often be found that a small-scale model test will offer the best solution of the problem, and the first illustration which I propose to give of the use of the principle of similitude deals with its application to statically loaded structures.

To the foregoing remarks it may be objected that if the application of the principle of similitude to problems of design means in general the making of small-scale model tests, then this principle is already in universal use in our testing laboratories, since the whole practice of testing materials involves the assumption that the resistance of any member of a structure can be predicted from that of a small specimen of the same material by making a test to destruction of it and assuming that the relative resistances in the two cases vary as the sectional area. Closer examination will show, however, that this practice means nothing more than a recognition of the fact that, as far as the resistance of members in direct tension are concerned, geometrical similarity can be ignored, *i.e.*, the limiting load may be taken as proportional to the area and independent of the contour of the section. It is now coming to be recognised that this assumption is not correct; that in the case of cast iron and the harder steels a sudden change in section will cause failure at lower values of the load per unit area than when the change of section is very gradual. Further, it is well known that the real use of the results obtained in a testing machine from tests to destruction of small specimens of the material from which large structures are to be made is to determine whether the characteristics of the material attain certain recognised standards of performance under this kind of test. Now, these standards are not only standards of resistance, but of permanent deformation, and in this latter case it is known

that to obtain the same standard from specimens of the same material, these must be geometrically similar if they are not all of the same dimensions.

This fact has now been recognised for some years by the Engineering Standards Committee in their specification for test pieces. In this sense, then, it may be admitted that scale-model testing is in use in our testing laboratories, and the question arises: Can its use be extended so as to be capable of application to scale models of the structures themselves? Obviously from the considerations already pointed out, if the weight of the structure itself is an important factor in the total loading, it is of little practical value, as shown by the conditions (1) and (3) of the table appended. If, however, the weight be negligible, an application of the principle of similitude (case 2 of table) shows that for geometrically similar and similarly loaded structures of the same material, if the stresses at corresponding points are the same, the loads must be respectively proportional to the square of the linear dimensions. Careful tests of similar structures of various kinds will show that under this law the comparison is a very exact one.

I exhibit now two sets of model struts which have been tested in this way. The calculation of the collapsing load of a strut of uniform section is a very simple matter, but when, for instance, it is made taper as in modern biplanes, for the sake of lightness, the calculation is somewhat tedious, and if facilities for making a scale-model test exist, I think it is probable that by such a test a more accurate prediction of the resistance of the full-sized strut would be made than by the use of the ordinary methods of calculation. In such tests it is, of course, of the utmost importance that the end constraints should be practically zero, and considerable care was taken to ensure this condition. The results showed that in both sets the collapsing loads were almost exactly proportional to the squares of the linear dimensions. The actual values obtained were:—

	Maximum load.
For the ½ size model	740 lbs.
	750 ,,
,, ¼ ,, ...	172 ,,
	196 ,,

Another illustration of the application of the principle of similitude to structures, which has been pointed out by Lord Rayleigh, is in the determination of the stresses set up by the impact of geometrically similar systems under the condition that the elastic limit of the material is nowhere exceeded. For greater generality we may take the case in which the densities of the systems are not the same. Assuming that the stress is dependent only on the linear dimensions, density, elasticity, and velocity of striking, the application of the principle shows (case 4 of table) that the law of comparison is

$$\frac{\rho_1 v_1^2}{\rho_2 v_2^2} = \frac{E_1}{E_2}$$

where ρ, v and E are the density, velocity of striking, and modulus of elasticity respectively, and that under these conditions the ratio of the stresses is

$$\frac{f_1}{f_2} = \frac{\rho_1 v_1^2}{\rho_2 v_2^2}$$

The interesting facts here brought out are that the stress ratio is independent of the linear dimensions of the colliding bodies, and that for systems of the same material equality of stress is determined entirely by equality of striking velocity. This was first pointed out by Osborne Reynolds in 1873 in a paper on the sand blast, in which he showed that the stress produced on the surface of glass subject to a sand blast was independent of the size of the particles. A consequence of this law which may appeal more to the present audience is that the elastic limit of an armour plate will be reached by any size of similar projectile having the same velocity of striking.

If we pass from this relatively simple case of impact to one in which the stresses are such as to cause fracture of one of the colliding bodies, as in the modern method of testing notched specimens, the law of comparison becomes complicated, and although considerable attention has been devoted to the subject by M. Charpy and others, as far as the writer is aware no definite means of comparing the results of impact tests on geometrically similar specimens under impact has yet been evolved. The form of specimen which has been standardised by the International Association of Testing Materials is one 30 mm. by 30 mm. in section with a notch 15 mm. deep and supported on knife edges 120 mm. apart. Of course in many investigations a specimen of this size cannot be obtained, and in this case a geometrically similar specimen to one-third scale is substituted for the standard one. Unfortunately it is found that the results of tests on these two sizes of specimen are not in agreement, even if the geometrical similarity be extended to the dimensions of knife edges and striking hammer. Thus for mild steel it will be found that the energy absorbed in fracture per unit volume is from 50 to 60 per cent. greater in the small specimen than in the large one. This is for the same velocity of striking, and it would appear, therefore, as if there were some speed effect which affected the deformation of the specimens. A research on this subject has been commenced at the National Physical Laboratory, and definite evidence of the existence of a velocity effect on the work of rupture has been obtained, but it is evident that the determination of the comparison conditions will not be an easy task.

TABLE.—*Conditions of Scale-Model Experiments and Comparison of Results.*

—		Conditions.	Comparison.
(1) Structure under own weight	Geometrical Similarity.	$\frac{E_1}{l_1 \rho_1} = \frac{E_2}{l_2 \rho_2}$	$\frac{f_1}{f_2} = \frac{\rho_1 l_1}{\rho_2 l_2}$
(2) Structure under external load only	,,	$\frac{E_1 l_1^2}{W_1} = \frac{E_2 l_2^2}{W_2}$	$\frac{f_1}{f_2} = \frac{W_1 l_2^2}{W_2 l_1^2}$
(3) Structure under own weight and external loads	,,	$\frac{W_1}{\rho_1 l_1^3} = \frac{W_2}{\rho_2 l_2^3}$ $\frac{E_1 l_1^2}{W_1} = \frac{E_2 l_2^2}{W_2}$	$\frac{f_1}{f_2} = \frac{\rho_1 l_1}{\rho_2 l_2}$
(4) Impact stresses within the elastic limit	,,	$\frac{\rho_1 v_1^2}{\rho_2 v_2^2} = \frac{E_1}{E_2}$	$\frac{f_1}{f_2} = \frac{\rho_1 v_1^2}{\rho_2 v_2^2}$
(5) Wave-making	,,	$\frac{g l_1}{v_1^2} = \frac{g l_2}{v_2^2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^3}{\rho_2 l_2^3}$
(6) Surface friction	,,	$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$
(7) Total resistance of ship	,,	$\frac{v_1^3}{v_2^3} = \left(\frac{l_1}{l_2}\right)^{\frac{3}{2}} = \frac{\nu_1}{\nu_2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^3}{\rho_2 l_2^3}$
(8) Thrust of propeller	,,	$\frac{g l_1}{v_1^2} = \frac{g l_2}{v_2^2}$ $\frac{n_1 l_1}{v_1} = \frac{n_2 l_2}{v_2}$ $\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$	$\frac{T_1}{T_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$
(9) Resistance of projectile	,,	$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$ $\frac{v_1}{V_1} = \frac{v_2}{V_2}$	$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}$
(10) Heat transmission from hot surfaces to fluids flowing over them.	,,	$\frac{R_1}{\rho_1 v_1^2 l_1^2} = \frac{R_2}{\rho_2 v_2^2 l_2^2}$ $\frac{k_1}{l_1 v_1 \rho_2 \sigma_1} = \frac{k_2}{l_2 v_2 \rho_2 \sigma_2}$	$\frac{H_1}{H_2} = \frac{l_1^2 v_1 \rho_1 \sigma_1 \theta_1}{l_2^2 v_2 \rho_2 \sigma_2 \theta_2}$

l = Linear dimension. v = Velocity. ρ = Density. ν = Kinematical viscosity. H = Thermal conductivity. σ = Specific heat. θ = Temperature difference. f = Stress. R = Total resistance. V = Velocity of sound. W = External load. E = Modulus of elasticity.

The case of scale-model experiments to determine the value of the resistance experienced by solids moving through fluids in which they are wholly or partially immersed may now be considered. The most important, or at any rate the best known, of these tests is Mr. Froude's method of obtaining an estimate of the wave-making resistance of ships, to which reference has already been made. The practical application of this method involves, of course, the separation of the resistance due to skin friction and eddy-making from that due to wave-making, since these do not follow the same law of variation with speed; and the obvious method of attacking the problem of the total resistance of a ship would be to discover, if possible, the law of comparison for surface friction and eddy-making and make another scale-model experiment for the determination of this second constituent of the resistance. It is a little remarkable that this law of comparison was discovered by Osborne Reynolds in Manchester at about the same time as the Froude Law of Comparison was enunciated by Mr. Froude. That no mention appears to have been made of it at the time may be either because the discoverer was too much concerned about the philosophical aspect of his work or, more probably, because he realised that the practical application of his law was out of the question, for the prediction of ship resistance at any rate.

The full statement of this law of comparison (case 6 of table) is, that in all cases in which the forces on a body moving in a fluid arise from the viscosity of the fluid, *i.e.*, the body is so completely submerged as not to set up surface waves, then provided the condition

$$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$$

is fulfilled, where v, l and ν are the velocity, linear dimensions, and kinematical viscosity of the fluid, the ratio of the resistances is given by

$$\frac{R_1}{R_2} = \frac{\rho_1 l_1^2 v_1^2}{\rho_2 l_2^2 v_2^2}.$$

This is the basis of all predictions of the resistance of aircraft and submarines from experiments on scale models in air or water channels. As regards its practical value in solving engineering problems, it will be seen at once that the difficulties in its application are enormously greater than in the case of the Froude Law of Comparison. In the latter case the model speeds are considerably lower than the ship speeds, whereas in the former the speeds are so great that for small-scale model experiments *in the same fluid* as that in which the structure moves the difficulties are insuperable. Thus if R and r are the total resistances of structure and model, we have

$$\frac{R}{r} = \frac{V^2 L^2}{v^2 l^2},$$

and since $v\,l = V\,L$, $R = r$. In the case of Mr. Froude's model of the "Greyhound" this would mean, if the experiment were made in water, a model speed of 320ft. per second and a pull on the dynamometer of 9,000lbs. It is, of course, not necessary that the two fluids should be the same, and if we could find a fluid whose ν is very much less than that of sea water the corresponding speed of the model would be proportionately less. Unfortunately, such a fluid has not been discovered, and there is not much hope that it will be. In the case of aircraft the difficulties are very appreciably reduced. Suppose, for example, that we are designing a dirigible balloon to move at 20ft. per second, and wish to find its resistance from a model of $\frac{1}{20}$th scale. In air the corresponding speed of the model would be 400ft. per second, and impossible to realise. If, however, we put the model in water, then since water has only $\frac{1}{13}$th of the kinematical viscosity of air, the speed would be 30ft. per second, and comes into the region of possibility. This is a very high speed for a water tank experiment, but if we were to heat the water to 80° C. we could reduce its viscosity by one-half and so bring the speed down to 15ft. per second.

It is not always realised that a determination of the complete resistance of a ship from a single experiment on a towed model could be made if a fluid of sufficiently low viscosity could be obtained in large quantities very cheaply. For example, the combination of the two sets of conditions

$$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2} \qquad \frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$$

leads to

$$\frac{v_1^3}{v_2^3} = \frac{l_1^{\frac{3}{2}}}{l_2^{\frac{3}{2}}} = \frac{\nu_1}{\nu_2} \text{ (case 7 of table).}$$

If, therefore, a fluid of, say $\frac{1}{64}$th of the viscosity of water could be produced, all that would be required to predict the complete resistance of a ship at 12 knots would be to tow a $\frac{1}{16}$th scale model of it at 3 knots in the fluid of low viscosity, and the total resistance of the ship would be 4,096 times the observed resistance of the model. It is, of course, the impossibility of finding such a fluid which necessitates the laborious and less accurate method of naval architects, which is, in the first place, to determine the wave-making resistance of the model by subtracting from its total resistance a value for its surface friction and eddy-making resistance which is calculated from experiments on thin plates towed in water. The value of the wave making resistance of the ship is then calculated from the above reduction, and to this is added another value of the surface friction and eddy-making resistance of the ship, also calculated from plate experiments.

Now, although the error in applying the results of plate experiments to the case of a ship's hull is certainly not a very large one, there is no doubt that this determination of skin friction is not nearly so accurate as the determination of the wave-making resistance. The reason is that the motion of the water round the hull is not similar to that relative to a plank, as may be seen by examination of the stream lines by the colour method. In the case of ships with fine lines, the breadth of the eddying belt at the stern is small, but as the lines become fuller the stream lines tend to break away and leave a comparatively large eddying region at the stern. If the extent of this region remained constant for a particular form of hull, a correction could be made for it, but it is known that it depends upon the speed, and therefore the surface exposed to skin friction is not the same for all speeds. It will be realised that the greatest possible care is required in making the calculations of skin friction with the existing methods.

Thrust of Propeller.—Another interesting example of the application of the principle of similitude is in the prediction of propeller thrusts from experiments on scale models of them in water or air. In this case, it will be necessary to consider the effect of size (l), revolutions (n), speed of advance (v), and the density (ρ), viscosity (ν), and elasticity of the fluid, and also in the case of water propellers, since the immersion is not generally so great as to prevent surface disturbance, the effect of gravity. Applying the principle of similitude, it is found that the law of comparison is a complicated one (case 8 of table), and involves four conditions, *i.e.*,

$$\frac{n_1 l_1}{v_1} = \frac{n_2 l_2}{v_2} \qquad \frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2}$$

$$\frac{g\,l_1}{v_1^2} = \frac{g\,l_2}{v_2^2} \qquad \frac{v_1}{V_1} = \frac{v_2}{V_2}$$

(where V is the velocity of sound in the fluid), and if these conditions are fulfilled, the ratio of the thrusts is

$$\frac{T_1}{T_2} \quad \frac{\rho_1 l_1^3}{\rho_2 l_2^3}$$

It is obvious at once that if only one fluid is available the conditions can only be fulfilled if $l_1 = l_2$, which appears to preclude any possibility of a small-scale model test. On consideration, however, it will be seen that the conditions are not all essential in practice, and that some of them can be violated without risk of appreciable error. In the first place, for water propellers, the ratio of the speed of the propeller blade tips to the velocity of sound in water is so small that no effect of elasticity of the water need be apprehended. Further, since the motion of the water round the blades is extremely turbulent, it is probable that the viscosity effect is negligible. The remaining two conditions can be satisfied, *i.e.*, the slips are made the same and the speeds regulated according to Froude's Law of Comparison. For aerial propellers the velocity of the tips may amount to from 300ft. to 400ft. per second, so that its ratio to the velocity of sound in air becomes appreciable. Recent experiments, however, appear to show that even at these speeds the effect can be neglected, and, therefore, since in this case there is no necessity for the observance of Froude's law, the assumption is now generally made that in air experiments the only condition for comparison is constancy of slip.

Resistance of Projectiles.—In considering the case of projectiles, the compressibility of the air becomes the most important factor

in the comparison owing to the fact that energy is being continually drained away in compression waves at the front and rear of the projectile. The law of comparison will, therefore, be (case 9 of table) :—

$$\frac{v_1 l_1}{\nu_1} = \frac{v_2 l_2}{\nu_2} \qquad \frac{v_1}{V_1} = \frac{v_2}{V_2}$$

and under these conditions the ratio of the resistances will be

$$\frac{R_1}{R_2} = \frac{\rho_1 \, l_1^2 \, v_1^2}{\rho_2 \, l_2^2 \, v_2^2}$$

Here, again, if the same fluid is used for both experiments—*i.e.*, $\nu_1 = \nu_2$ and $V_1 = V_2$—no small-scale model experiment is possible. If the viscosity effect be neglected as relatively unimportant, an assumption which appears to be justified, the law of comparison becomes that of equality of muzzle velocities. It is of interest to note that the change of medium for the model experiment from air to water which was found to be helpful in the case of models of aircraft presents much greater practical difficulties for projectiles. Thus, if we carry out the model experiment on the model projectile in water, since the velocity of sound in water is about four times that in air, the speed of the model in water would have to be four times that of the full-sized projectile, or, say, 9,000ft. per second. The comparison condition would then give a value of the linear dimension of $\frac{1}{4} \times \frac{1}{13} l$, or $\frac{1}{4}$in. diam. for a 13in. shell.

Heat Transmission.—The last illustration will be that of the application of the principle of similitude to problems in heat transmission from heated metal surfaces to fluids flowing over them. This is of special interest at the present time, since it bears on researches on the possibility of increasing the speed of aeroplanes by the use of air-cooling of petrol engine cylinders instead of the ordinary method of water cooling. As regards convection of heat, the theory was laid down by Osborne Reynolds that from the identity of the two molecular phenomena by means of which convection of heat and convection of momentum or surface friction were carried on, their dependence on the conditions of motion of the fluid would be the same. From this it follows that in the case of a fluid at temperature t, flowing at a velocity of v through a pipe whose surface is maintained at a temperature T_s, the heat transmitted per unit area by convection would be

$$R \frac{(T_s - t)}{v} \sigma$$

where σ is the specific heat per unit mass at constant pressure, and R is the skin friction per unit area. It was pointed out by Reynolds that this value would not be strictly correct, since ultimately the heat is transmitted from the metal to the fluid by pure conduction through a thin film at the walls, so that a factor depending on the conductivity would be needed. It is, of course, possible to investigate the form of this factor by making certain assumptions as to the thickness of the surface film (which is certainly too thin to admit of direct measurement) ; but a hopeful method of attacking the problem would appear to be by scale model experiments when once the law of similarity has been obtained. To do this, assume that the heat transmission (H) depends on the linear dimensions (l) and surface friction (R) of the pipe, and on the specific heat (σ), density (ρ), thermal conductivity (k), and speed of the fluid (v), and on the range of temperature between metal and fluid (θ). The application of the principles then gives for the law of comparison

$$\frac{R_1}{\rho_1 v_1^2} = \frac{R_2}{\rho_2 v_2^2} \quad \text{and} \quad \frac{k_1}{l_1 v_1 \rho_1 \sigma_1} = \frac{k_2}{l_2 v_2 \rho_2 \sigma_2}$$

and under these conditions

$$\frac{H_1}{H_2} = \frac{l_1^2 v_1 \rho_1 \sigma_1 \theta_1}{l_2^2 v_2 \rho_2 \sigma_2 \theta_2} \quad \text{(case 10 of table).}$$

It would seem, therefore, that in this case an investigation of the problem by model experiments might prove a very fruitful research.

In conclusion, it is hoped that the foregoing brief sketch of the application of the principle of similitude to some of the problems of the engineer may tend to correct an impression which is still prevalent that there is only one law of comparison for scale-model tests, and, further, that it may afford some indication of the value of the method in determining when a scale-model test is possible, and the precise conditions under which it must be made if the results are to be reliable.

THE IDEAL ELECTRIC FURNACE FOR THE STEEL FOUNDRY.*

BY F. J. RYAN, E. E. MC.KEE, AND W. D. WALKER.

A SHORT study of all electrical steel furnaces now admitted to be practical will show that the great simplicity in operation and construction of the single-phase or single-electrode furnace eliminates confusing details, and makes it possible for the foundry to change from converter or crucible steel practice to that of electric steel with least loss of time and with least change in the existing organisation.

For foundry work the electric steel furnace converts a charge that consists almost entirely of scrap steel, and it is the grade of scrap available which largely determines the lining to be used. Where the scrap has the same phosphorus and sulphur content as is desired in the finished product, the acid lining is the most satisfactory and economical in practice ; (1) because of the ease and simplicity of operation ; (2) because of the difference in cost between acid and basic lining material ; and (3) because of the greater heat loss when refining on a basic lining. Where the phosphorus and sulphur must be lower in the finished product than in the charge, or where it is not possible to secure selected scrap the analysis of which is known, the basic lining must be used because only on a basic lining can the phosphorus and sulphur be reduced. In the production of many special steels where no reduction of phosphorus or sulphur or both is necessary, the basic lining is also used because the alloy content can be more readily controlled to the definite points that are desired, and the loss in alloy addition is less.

On the other hand, this reducing of the phosphorus and sulphur on a basic bottom, or holding the heat while making alloy additions and awaiting determinations, adds considerably to the cost of production. The fundamental principle in electric steel furnace construction is the proper application of heat and the reduction of heat losses. Heat may be conserved as well in a basic as in an acid-lined furnace, except for the additional loss due to radiation resulting from the increased time necessary to refine the metal. It is an advantage to have a way to reduce the voltage and the power input while holding the metal for refining, so as to minimise this loss and to save the linings and the steel from overheating. As regards the application of the heat, single-electrode practice differs radically from three-electrode furnace practice in the speed of melting down, but in any event both single and three-electrode furnaces are now operating on both basic and acid linings with commercial results.

A basic lining usually is built up of magnesite, dolomite, magnesite brick, or some combination of these materials. The roof of the furnace is ordinarily of silica brick as in acid practice. It should be possible with any electric steel furnace to change from acid to basic or vice versâ whenever desired. In such a furnace the foundryman can use the lining best suited to conditions in the scrap market.

The electric steel furnace which produces the finished product in the shortest possible time is the most economical as regards power consumption, for the reason that the actual power needed for the conversion of the charge is the same in all cases. The reason why a single-electrode or single-phase furnace can produce the finished product in a short space of time is because in the single-phase furnace it is possible, with a high voltage and a long arc, to put into the furnace more power within a given period of time.

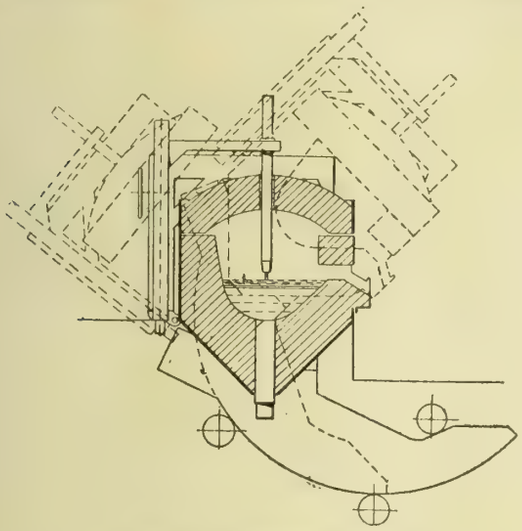
The simplicity of the electrode-control apparatus in the single-electrode furnace has made it possible to develop the open-roof type electric steel furnace, a cross-section of which is shown in the accompanying illustration. This type allows quick charging, preferably by mechanical means, thereby increasing the number of heats and cutting down heat losses during charging. By plastering up the juncture of the roof and the body, and closing up the spout with a sliding door, the furnace can be almost completely sealed up while melting down. There is, of course, no weakness in lining structure with such a furnace. This open-roof type of electric

* Abstract of paper read at the recent annual meeting of the American Foundrymen's Association, September, 1916.

steel furnace has been thoroughly tested, and is presented not as an idea, but as a working and practical design. A number of these furnaces are now in commercial operation.

The question naturally arises whether quick, small heats are an advantage over larger heats at longer periods in other words, whether the steel foundry can take care of 10 to 12 small heats in 24 hours better than it can take care of six to eight larger ones. This comes down to the practice in the individual foundry, but without a doubt the majority of foundries would find it more convenient to take off five heats per 12 hours or 10 heats per 24 hours rather than three and six heats over the same periods.

The number of heats that can be secured from an electric steel furnace also has an important bearing upon the consideration of the initial price of the equipment. The logical method of measuring the capacity of electric steel furnace equipment is by output over a given period of time, and not by holding capacity. The furnace which can produce the



OPEN-TYPE OF ELECTRIC FURNACE.

greatest amount of material over a given period of time is the most economical unit. The single-electrode furnace delivers the quick heats and allows great production.

TABLE I.—*Operation of a ¾-ton Single-electrode Basic Furnace at the Gerlinger Steel Casting Company, Milwaukee, January, February, and March,* 1916.

Total output, tons	274·23
Total electricity, kw.-hr.	146,160
Average kw.-hr. per ton	533
Average lbs. per heat	1,885
Average cost per ton metal in the ladle	$28.93

In Table I. is a summary of the results obtained in a ¾-ton single-electrode Snyder furnace in the plant of the Gerlinger Steel Casting Company, Milwaukee, Wis. This furnace was lined basic. It was guaranteed to produce three tons of steel per 12 hours with power consumption at the furnace not in excess of 880 kw.-hrs. per ton of steel. In actual practice the furnace has often produced four heats of 2,000lbs. for a total of four tons in slightly more than 11 hours. The power consumption on the primary side of the transformer averaged only 533 kw.-hrs. per ton over the period of three months. A larger single-electrode furnace has since been installed by this company, and is now operating with satisfactory results.

A record of a complete day's run in the plant of the Dayton Steel Foundry Company, Dayton, O., showed that in the total time (24 hrs. 40 mins.) the total output was 27,800lbs.; the average charging time, 22 mins.; average melting time, 72 mins.; average pouring time, 12 mins.; and average time per heat, 106 mins.

This performance, the production of 14 heats of a ton apiece, melting cold steel scrap, over a period of 24 hrs. and 40 mins. is hard to believe. The furnace which made this run is a 1½-ton single-electrode furnace lined acid. The question naturally arises why this furnace was charged with only 2,000lbs. if it is a 3,000lbs. furnace. This depends upon the practice in the individual foundry. Some overload and some underload their furnaces. In a similar furnace to that at Dayton, the Crucible Steel Casting Company, Milwaukee, Wis., has charged up to 3,800lbs., and averages above 3,000lbs.

The various items that enter into the conversion cost include labour, refractories, electrodes, repairs, accessories, electricity, and overhead.

Labour. On a furnace up to ¾ ton size only one operator, a melter, should be necessary. On larger furnaces this melter should have an assistant. The common labour will not involve a given number of men, as the work around the furnace is not sufficient to require all the time of the labourers. They will be needed a part of the time for wheeling the scrap, for taking care of the ladles, and for charging the furnace. The size of the furnace, the lay-out of the foundry, the method of charging, and the method of pouring will all affect this cost.

Refractories.—The life of the roof and linings depends largely upon the care of the furnaceman and the practice in the individual foundry. It is easy to point out isolated cases, such as that of the Crucible Steel Casting Company, Milwaukee, where one roof on an acid-lined single-electrode furnace lasted more than 650 heats. Generally speaking, the roof and side walls of an acid-lined furnace should last from 200 to 250 heats. The bottom of both basic and acid-lined furnaces should last for a year or more.

Electrodes.—The electrode consumption will also vary according to the care taken by the furnace operator. It is easy to point out other isolated cases, such as the Crucible Steel Casting Company again, where the electrode consumption over several months averaged between 2½lbs. and 3lbs. to the ton of steel. In practice, the consumption will range from 3½lbs. to 5lbs. per ton of metal in the ladle.

Repairs and Accessories.—Repairs and accessories are a very small item of the conversion cost. They will add about 1s. 3d. per ton on a ¾-ton furnace, and will gradually decrease as the sizes of furnaces grow larger.

Electricity.—The cost of the power will be affected by whether the furnace is operating on straight melting down or on melting down and refining. The method of charging is important, and the time required dependent upon whether hand or mechanical means are used. The amount of care taken in killing the metal will be another important item. The Dayton Power and Light Company advise as follows: "From all the records we have on the Snyder electric furnace installed by the Dayton Steel Foundry Company, the current consumption has not exceeded 480, in fact, the average is between 470 and 480 kw.-hrs. per ton of steel." The record at Dayton is on straight melting, on an acid-lined furnace, using good scrap.

Overhead.—The authors' practice is to charge burden in at 20 per cent. to cover interest, depreciation, and taxes. The charge and additions will vary in relation to the market.

The electric furnace, no matter of what type, has now passed beyond the experimental stage and has entered into actual commercial operation, entirely separated from chance or unknown results. The steel foundryman can feel that in interesting himself in the electric steel furnace he is making a step forward in his field and business. Observations of foundrymen and investigations made by men prominent in the steel industry show clearly that steel produced in the electric furnace has a greater strength and a more uniform structure than steel from the converter, open-hearth or crucible. This being so, the foundryman can only ask himself whether or not his business demands a change, and whether or not competition from outside sources, where electric furnaces are being used, is not liable to endanger an established business that he has built up. Manufacturers are basing their purchasing requirements more and more upon figures of specific performance and actual tests. This is tending to eliminate the personal element that business has had for many years. Therefore, it will be a question of quality and price that hereafter will largely determine the volume of business that any steel foundry is liable to obtain. If quality and price are to be the standards upon which the volume of business is to be based, necessarily the foundryman, when he begins the investigation of electric steel furnaces, should convince himself thoroughly that the unit he buys will be the most practical for his requirements, and will produce his steel for the lowest unit cost.

NEW TYPE OF BALANCED ROTARY VALVE.

WITHIN the last few years a number of different types of valves, for automobile gas engines, have been invented, the purpose being to overcome some of the many disadvantages of the poppet valves. The principal desirable features for automobile engine valves are as follows: Noiseless operation, simple and substantial construction, light weight, small consumption of power, large port openings, high opening speed, no possibility of being damaged by lack of oil, long life of valve, little wear from use, perfect cooling and oiling under all conditions of operation. The following design, presented by Mr. R. J. Gilcher in the "Sibley Journal of Engineering," is the outcome of an attempt to produce a valve embracing the largest number of the most desirable features.

Referring to Fig. 1, the conical valve 1, which rotates at half-crankshaft speed, has a single port 2 registering with the inlet 3 and exhaust 4 ports formed in the cylinder head. To the hollow shaft 5, which is an integral part of the valve, is fastened an equaliser 6 that rotates with the valve. The equaliser contains two rings making the space above it gas-tight. The object of the equaliser is to equalise the pressure of the gas in the cylinder against the valve. During explosion a very small amount of gas passes up through the hollow shaft and fills the space above the equaliser. The equaliser is of such size that the pressure of the gas down on it is equal to the pressure of the gas upon the valve. In the actual engine the size of the equaliser is slightly less than as stated above, so there will be a slightly greater pressure of the valve against its seat during expansion. This ensures that the leakage of gas will be a minimum consistent with the power required to operate the valve and conditions of oiling. The pressure curve of the valve against its seat is as shown in Fig. 2. The spring

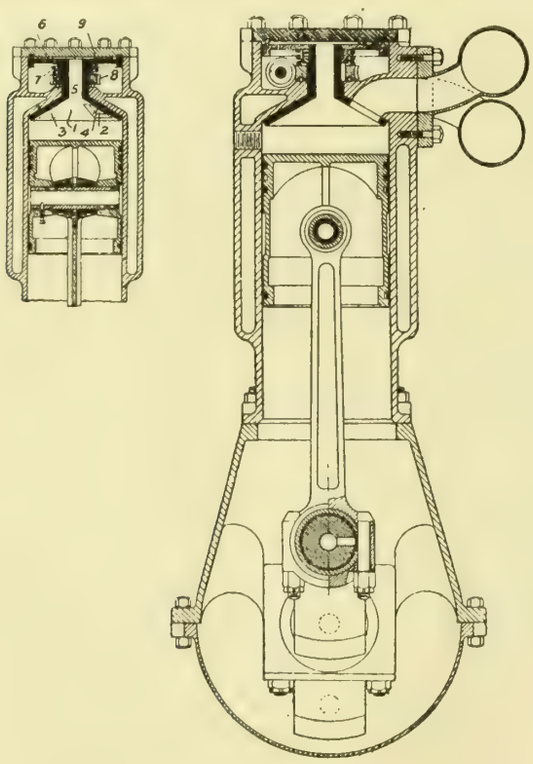


FIG. 1.—BALANCED ROTARY VALVE.

7 has the double purpose of holding the helical gear 8, which is keyed to the shaft so as to allow a slight vertical motion with respect to the stem, down on the ball bearing and up on the valve equaliser, so as to keep the pressure of the valve against its seat constant. The size of the equaliser and the spring are so constructed that the power required to operate the valve is a minimum, consistent with leakage and oiling conditions as stated above. At 9 is shown a set of concentric rings, the centre being vertically over the geometric centre of the valve port. The functions of the rings are to reduce the pressure on the equaliser by an amount equal to the reduction of pressure due to the valve port. During explosion, as the gas tends to pass the reduction rings, eddy currents are set up between the rings which prevent the flow of the gas. Since the flow of gas is an intermittent transient flow, the rings are therefore very effective. At the centre of the rings is a small hole which allows any gas that has passed the rings to flow out so that the effective pressure inside the rings will be zero.

The valves in the motor are driven by a shaft passing through the head of all the cylinders. Each valve is geared

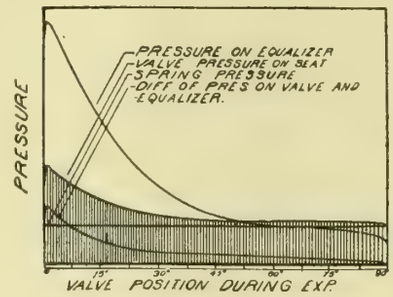


FIG. 2.

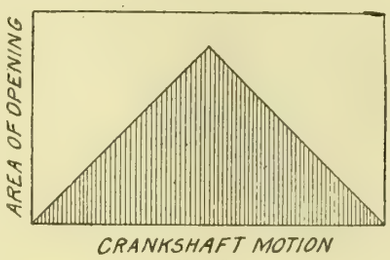


FIG. 3.

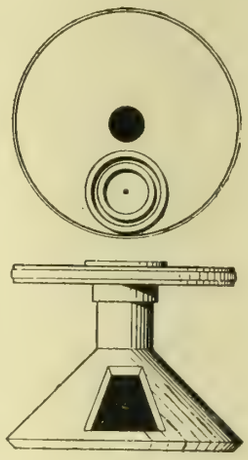


FIG. 4.

BALANCED ROTARY VALVE.

to this shaft by a pair of helical gears, the shaft rotating at twice the valve speed. The horizontal shaft is geared to the crankshaft through a vertical shaft in the front of the motor which also operates the fan. Only helical gears are used in the motor, which makes the operation absolutely silent. With the motor running at constant speed, all parts of the valve also rotate at constant speed. The only parts of the motor that reciprocate are the pistons and connecting rods.

The shape of the combustion chamber is almost ideal, having no pockets to cool the gas and lower the efficiency of the engine. The valve ports are large and give an opening curve as shown in Fig. 3. The surface of the valve seat is conical (Fig. 4), and therefore is not affected by wear from use. The valve seat faces downward, which prevents any collection of carbon. It is an easy matter to oil the bearing surface of the valve since the bearing pressure is low and nearly constant. Due to the low bearing pressure the power required to operate the valves is very small, and is a negligible portion of the power output of the motor.

ELECTRIC POWER DISTRIBUTION.*

BY CHARLES H. MERZ.

(*Concluded from page 272.*)

AN urgent matter for settlement is the standardisation and unification as rapidly as possible of the frequency and voltage adopted for distribution purposes in neighbouring localities. Electrically this, as I have said, is as important as having all the railways of uniform gauge. It is not proposed that uniformity of frequency and voltage should be established throughout the whole country, as this would entail the scrapping of a very large amount of valuable plant, but there would be no difficulty (and considering the issues at stake, comparatively little expense) in standardising a single frequency for each of the industrial areas of the country, as follows:—

Midlands	25	cycles.
West of Scotland	25	„
North-east Coast	40	„
Lancashire	50	„
Yorkshire area	50	„

* Paper read before Sections B and G of the British Association at Newcastle September, 1916.

As regards the voltage, this will require careful consideration; on the North-east Coast we have standardised 20,000 volts, and in some of the other areas 10,000 volts has been adopted, but it is a question whether this is not too low for main trunk lines. The question is, who is to pay for this unification? It is not, in general, the fault of the existing undertakings that they have adopted different voltages and frequencies to those in vogue in the surrounding industrial districts—though in some cases it must be admitted that it has been their desire to remain isolated, whatever the interests of the country in general and their own consumers in particular. The chief fault lies at the door of the nation itself—the Board of Trade having in the past even encouraged, in some cases, the establishment of different systems in adjacent areas.

The Board of Trade already has a right to say what system (electrical) shall be adopted as regards all new undertakings or existing undertakings developing newly acquired areas. The Local Government Board, in the case of municipal undertakings only, as loan authority, has control over expenditure on extensions of plant and mains by municipal electrical undertakings. As regards municipal undertakings which propose to adopt or extend electrical systems (plant or mains) of a type which would be inconsistent with development on uniform lines throughout the area in which they are situated, the Local Government Board could attach a condition to the loan to prevent this. The privately-owned concerns are not, of course, subject to Local Government Board control, but the powers of the Board of Trade as regards the sanction of systems to be adopted would probably be sufficient, and in any case the large power companies, who are the most important of the private concerns, operating as they do over large areas, are already fully alive to the necessity for standardisation and unification.

What is important is that a main inter-connected electrical power-distribution system should be established in each industrial area as soon as possible. Just as trade between different parts of the country would be impossible, or practically impossible, without railways, so trade in power—that is, the supply of power where most required, from the source where it can be most economically generated—is impossible without a trunk main. The electrical "roads" of the country must be standardised and made just as the railroads have been. To-day, if a colliery owner has small and poor coal in his colliery which it does not pay him to bring up because it cannot stand the cost of transport, he cannot contemplate turning it into electricity at the pit mouth—extracting the by-products in doing so—because, except in certain areas where a trunk-main system exists, there is no market for the electricity, there being no means of distributing or transmitting it. Each individual colliery owner cannot establish his own electrical-distribution system to neighbouring towns or manufacturers any more than each manufacturer can provide his own railway system for distributing his goods. If a man has waste heat—or could, by improving his manufacturing or chemical process, combine it with the generation of power—there is no one to take his power, because the "roads" are not there to carry it; and in most districts the large towns, where the concentrated loads already exist, are not electrically connected with adjacent industrial and colliery areas.

In the above remarks I have considered the matter chiefly from the point of view of saving fuel; it is worthy of note, however, that inter-connected electrical-power distribution systems are essential if the capital charges and labour costs, which are very important items in the production of electricity, are to be kept to a minimum. This arises from the fact that it is only by supplying all the needs of the community from one system that the maximum use can be made of the plant. As a great many individuals in a given community do the same thing at the same time, what we must take advantage of is that the individual does not and cannot do half-a-dozen things at once. The economy of the combination of all requirements, power, traction, heating, and lighting is fundamental. To show how far we are from this ideal let us take the case of London.

A man lives, say, in Hampstead; he cooks his breakfast, if he can buy electricity sufficiently cheaply, by electricity supplied from one station; he travels to his office by electric train supplied by electricity from another station; his office in the City is supplied by electricity from a third station; probably he gets his lunch at a restaurant supplied by electricity for light, &c., from a fourth station; if he has to go out of the office and visit other people in the afternoon he travels probably by a tram supplied by a fifth station, he may eat his dinner at night in a West End restaurant supplied from a sixth station, go to a theatre supplied from a seventh station, and so on. So that an inhabitant of London may quite well require throughout the day anything between five and 10 sets of plant to supply his needs. In other words, the capital costs of supplying him are increased five or six-fold.

London Electricity Supply. Present Position.

	Central Area.	Greater London.
Number of authorities	39	70
Number of generating stations*	41	70
Average size of stations	7,646 kw.	5,285 kw.
Average size of units	787 kw.	632 kw.
Number of types or systems of generation	31	49
Number of frequencies	8	10
Number of voltages { Generation	20	32
Number of voltages { Distribution	21	24
Number of methods of charging and prices	Over 50	Over 70

* In addition there are nine traction stations within the Greater London area, eight of which are within the Central area.

This is a result altogether apart from the fact that, due to the enormous number of systems and stations in London, the plant used is of ridiculously small size, and therefore the efficiency as regards coal consumption is very low—in fact, the average efficiency of conversion from coal to electricity in London to-day is only a third of what it would be under any modern scheme. What applies to London applies equally to other industrial districts if we substitute the factory for the office.

It may be well, in conclusion, to summarise the advantages and economies resulting from electrical development on correct lines: (1) A large saving in coal as a result of the erection of plants of the most economical size, according to the load, in the best positions. (2) The utilisation of waste heat. (3) The utilisation of coals which are too friable for transport. (4) The utilisation of coals now left in the pits because their value will not stand the cost of transport, and of other combustible materials not at present used as fuel for the same or other reasons. (5) The development of new carbonisation and distillation processes. (6) The more general use of electrical energy for all purposes, *e.g.*, industrial power, rail traction, metallurgical, electro-chemical, and furnace work, and the development of industries which it has hitherto not been possible to carry on in this country. (7) Increased industrial output as a result of a greater use of power in consequence of its lower cost. (8) A general improvement in the efficiency of prime movers by British manufacturers, which cannot but have a marked effect on all power-generating machinery (including that for marine purposes) and on our foreign trade. The British manufacturer can only compete with those of other countries if the things he has to sell are as good or better. In the case of the largest prime movers there are at present only two purposes for which they are used on a large scale, namely, for marine purposes and for driving electric generating plant. It is a fact that, in recent years especially, the larger prime movers have invariably been developed for land purposes first, the marine engines following, *e.g.*, the Parsons turbine and the large internal-combustion engine. One reason for this is that the experimental work involved in developing new types and larger sizes of prime movers is more easily and more economically carried out ashore. Hence it is clear that the development of electric supply on right lines affords the best field for progress in design and economy.

What is fundamentally and immediately necessary is the establishment of a national electrical trunk mains distribution system. Proceeding on these lines we shall not be merely copying America or Germany—we shall be doing something that is right for England because it is England, and because England is radically different from other countries as regards the technical development and "lay out" necessary to secure cheap power. We have delayed making a start on right lines 15 years longer than is necessary; let us delay no longer.

THE ENGINEER IN THE STEEL FOUNDRY.*

BY JOHN HOWE HALL.

PROBABLY the best way to point out the desirability of co-operation between the designing engineer and the maker of steel castings is to give, from the foundryman's point of view, some of the difficulties encountered in endeavouring to execute contracts for engineers who are not sufficiently acquainted with foundry practice to design and specify castings correctly, and who have not learned the desirability of personal contact with the foundryman who is to make the casting. I think most foundrymen will agree with me in saying that their difficulties in this line may be classified under two headings: Difficulties with physical and chemical specifications, and difficulties in trying to make castings of a design not suited for steel foundry work.

Specifications that have come to the notice of the author, that cannot well be executed, can be divided into several general classes. The first of these is that specification which includes unusual chemical or physical tests. Thus at times the specification says that the steel must contain not over a very small amount of phosphorus or sulphur, and that amount so small that it can be secured only with steel of the very highest grade made in the electric furnace or in crucibles. In many cases it is found upon investigation that the price which is to be paid is not sufficiently high to warrant the use of very pure material in crucibles to meet the chemical requirements or to warrant the use of electric furnace steel. It will frequently also be found under these circumstances that the castings do not need to be particularly strong nor tough, and when the engineer drawing the specifications is open to conviction, a compromise is often reached by which the regular steel turned out in the shop is used to execute the order with perfect satisfaction to all concerned.

Again, specifications come in which call for a manganese content not over a figure which is now known to be quite low for good steel. Frequently the men who are bidding on the order are in the habit of using a great deal more manganese than the specifications allow, and know, from long experience and extended tests on their steel, that the high manganese steel they make is more satisfactory than steel made in accordance with the specifications in question. A little conversation between the specifying engineer and the foundryman generally clears up this difficulty, and the foundry is allowed to use its regular grade of steel. This difficulty with manganese specifications probably arises from the opinion generally held 20 years ago, that manganese over 1 per cent., or even a little lower, caused brittleness in steel. More recent researches, of course, have shown that under proper conditions a good deal more than 1 per cent. manganese can be used in steel not only with perfect safety, but with great advantage.

At the present time, owing to the high price and scarcity of ferro-manganese, the foundryman in many cases is anxious to use not more but less manganese than the specifications call for. In a great many cases his engineers have made extended tests of their steel and found that by the use of special alloys or special procedure they are able to make perfectly satisfactory steel with less manganese than the specifications call for. In these cases, if the steel can be shown by tests to be perfectly satisfactory for the service desired, it is manifestly unfair to compel the unfortunate steel maker to use more manganese than he has found necessary.

Another case in which the chemical specifications become a stumbling block is when alloy steel is specified, and the foundryman is quite sure that a good grade of ordinary carbon steel is best for the purpose. It should be said in all fairness that this class of specification is rather rare, and that in most cases it is accompanied by a failure to specify the amount of the alloy in question that is desired in the steel. Thus specifications are received calling for chrome steel, or nickel steel, or vanadium steel, with the amount of the alloy not specified. In some cases these orders are finally executed in a good grade of ordinary steel; in others the correct amount of the alloy to best suit the conditions is used by the foundryman; and in still others the order is turned down because it is not worth the foundryman's while to go to the trouble and expense of using the alloy in question for an order which does not amount to a great deal in total value.

Another troublesome specification, which is probably more often met by makers of special steels for abrasive wear than by the ordinary foundryman, is the specification calling for a very high elastic limit in the steel. In some cases this elastic limit is higher than it is possible to reach with a steel casting; and in other cases, the equally troublesome fact is found that the elastic limit specified is so high that the steel is not machinable and considerable machining has to be done on the casting. Where the machining is done in the foundryman's shop, it is, of course, possible sometimes to rough machine the casting, then heat treat for the desired physical properties and then grind to shape. There are, of course, a certain number of cases where this procedure is necessary, because the steel must have the physical properties called for. But in the experience of the author, there are a number of cases in which the very high elastic limit is called for by the designing engineer with the expectation that the steel can be machined after heat treatment. Under these circumstances, of course, unless the engineer and the foundryman get together personally or by letter and have a heart-to-heart talk, someone's feelings are going to be hurt when the order is delivered.

In a certain number of cases, an elastic limit is specified which cannot be secured without special heat treatment of the steel, and the design of the casting is such that it is impossible to heat treat it without cracking it. Such cases, of course, can be taken care of either by modifying the elastic limit called for, or by so modifying the design of the casting as to eliminate the danger of cracking it in the heat treatment. The author is familiar with a great many cases where this difficulty has arisen, and has seen it taken care of, sometimes by one method and sometimes by another. Still another class of specification which has come to the author's attention is that in which an alloy steel of one kind is specified for a class of service in which, according to the experience of the foundry executing the order, an entirely different alloy steel will give very much better results. This, in some cases, may be an instance where the foundry could learn from the engineer, as well as the engineer from the foundry. Thus if the engineer is specifying the particular alloy steel that he does specify in the belief that it will be good for the class of service in question, but without definite experience to prove his belief, he may find the experience of the foundryman with that class of service of great value to him. On the other hand, the engineer may have made previous experiments with both classes of steel and have found that, in his particular case, the class he specifies is, for some reason or other, better suited to the service than the class of steel the foundry has been in the habit of furnishing. When this is the case, of course the foundry can secure valuable information from the engineer. Of course, in some instances the engineer is specifying the new class of steel in an experimental way. If he and the foundryman get together and discuss the question, the engineer may find that it will not be worth while to try his experiment because the foundry has tried it already. On the other hand, the foundry may well find that the engineer has good reason for trying his experiment, and by keeping in touch with the order and ascertaining its performance in service the foundryman may secure valuable data.

Another class of specification that gives great difficulty to the foundryman is that specification in which both the chemical analysis of the steel and the physical properties which it must show are given in the specification. Sometimes, indeed, this is further complicated by the addition of a specified heat treatment. In many cases, of course, the analysis and the heat treatment specified will give the physical properties desired, but in far too many cases the foundryman on reading the specification finds that the physical properties called for cannot be secured in a steel of the analysis specified, or perhaps that the properties can only be secured by a heat treatment which is not allowed in the specification. Under these circumstances, the foundryman, in the lack of further data, is obliged to take his choice between making a steel which meets the chemical specification, and making a steel which shows the physical properties desired. Of course, if he discusses the matter with the

* Presented at the annual convention of the American Foundrymen's Association, September, 1916.

specifying engineer, it can very soon be straightened out by altering either the chemical specifications or the physical specifications.

A little consideration of the foregoing discussion will show the great value to both the specifying engineer and the foundryman of standard specifications prepared by societies of recognised standing, and adhered to by both the makers and the buyers of castings; but even some of these specifications prepared by national societies of recognised standing sometimes fall into the error of over-specifying. Thus, until this year the specifications of one American society, if literally adhered to, would have ruled out of consideration all the ordinary steel castings made in a certain shop. The reason for this was that the specification as it read gave the physical properties desired in the steel, and also the method of heat treatment by which those physical properties should be secured. As it happened, the heat treatment specified was perfectly satisfactory to secure the desired physical properties in certain classes of steel, but the foundry in question was accustomed to secure the physical properties by special heat treatment of steel of a different class, and this heat treatment was forbidden by the strict letter of the specifications.

Too much stress cannot be laid on the importance to the foundryman of securing uniformity of specifications for steel castings on the part of various representative societies. To take a case in point, the author at one time had experience with an order for steel castings which formed parts of a steamship. It happened that these castings had to be accepted under three different specifications, all of them gotten out by well-known organisations. These three specifications so overlapped that it was necessary to secure a steel having a very narrow range of tensile strength. The steel as finally turned out passed all the specifications except one, and it would not meet this specification because it had about 4,000lbs. too much tensile strength. The inspectors who were working under this third specification refused to accept the castings because while they showed considerably more extension, contraction, and bend than was called for, and while the elastic limit was perfectly satisfactory, yet the steel was too strong. It seems almost too absurd for belief, but efforts had to be made to so heat-treat those castings as to take 4,000lbs. or 5,000lbs. off the tensile strength, and it was found impossible to do this without making the castings fail in some other part of the specification. After a great deal of bother, the matter found its way up to higher authorities, and the steel, of course, was then accepted as being a good deal better than the specifications called for.

The second great source of trouble in the steel foundry which can be remedied by co-operation between the designing engineer and the foundryman, is the design of the casting. There are so many ways in which a design can be unsuitable for foundry work that it is not possible to mention all of them. Aside from the rather obvious error of specifying a casting so thin that it cannot be run in cast steel at all, the more common errors are, so designing a casting that it cannot be made without showing bad cracks, or designing it so that it cannot be made truly sound. The shrinkage of cast steel, being considerably higher than that of grey cast iron, is chiefly responsible for the difficulties with cracked castings. In many cases, of course, this is aggravated by higher sulphur in the steel than is desirable, and by the necessity of pouring the castings very hot.

In a great many cases a customer who has been buying grey iron castings sends in his patterns to the steel foundry and desires to have them executed in steel without change of design. The foundryman looks the patterns over, and sees, for instance, that they contain thick and thin sections joining at a sharp angle, and that it will not be possible for him to provide fillets or brackets at the junction of the two sections sufficiently strong to hold the casting together. Again, he may see that fillets at the junction will serve to prevent the casting from cracking in cooling, but he finds that the engineer is unwilling to allow him to use these fillets. If the designer and the foundryman go over this matter together, it will generally be found that fillets can be used and in some cases, of course, removed after the casting is finished; or, again, that the design of the casting can be so changed as to make the sections far more uniform. The author has known many cases, which are probably common to the foundryman's experience, in which the casting could not be made without serious cracking unless the distribution of the metal in the sections is radically changed. In some cases the casting will crack in cooling in the mould, and in some extreme cases it will come out so crooked that it will break in straightening or else give great trouble in straightening, as this is sometimes done while hot.

Those who have had practical experience with the manufacture of alloy steels requiring special treatment know very well the difficulties of trying to execute castings in special steel that can readily be turned out in ordinary carbon steel. When patterns are sent in to us which were designed for ordinary steel with the request that we execute them as they stand, we are frequently in hot water, and finally either execute the castings with a change of design or let some other maker get costly experience trying to make them. In the cases where the pattern was designed for execution in cast iron, and is sent to us for execution in our special steel, the temperature of the hot water we get in is even higher. Our difficulties are considerably increased by the fact that the shrinkage of our steel is unusually high, so that we may have a casting crack in cooling; we may have it crack in heating up in the furnace, and again we may have it crack in straightening, especially as it is not feasible for us to put heat on our castings after their treatment is completed.

Sometimes castings are so designed that it is virtually impossible to make them truly sound. This is generally owing to the fact that the sections are so distributed that there is no place to put a sink-head of sufficient size or proper design to feed the fluid shrinkage of some heavy sections. The author has known many cases where conference with the designing engineer has led to a change in the pattern which enabled the casting to be made truly sound, and he regrets to state that he also knows of cases where no change was allowed and the foundryman just had to do the best he could. It is some satisfaction to state, however, that in a certain number of these cases he knows of the failure of the castings owing to almost complete unsoundness of some interior and important part, and that in those cases the designer of the castings generally had to accept the responsibility and to modify his design in accordance with the suggestions originally made by the foundry.

NEW SURFACE COMBUSTION ANNEALING FURNACE.

Two annealing furnaces are now in operation at the plant of the Remington Arms Company, Eddystone, Pa., employing the surface combustible principle and giving a neutral or reducing atmosphere which makes it possible to treat the forgings without packing or otherwise protecting them against oxidation. The surface combustion system of utilising gaseous fuel involves the delivery of the gas against or through refractory material, with the result that the surface of the incombustible material becomes and remains incandescent. The present installation was designed and installed, under patents granted to Prof. Charles E. Lucke, of Columbia University, by the Surface Combustion Company, 30, East Forty-Second Street, New York. The furnaces, one of which is shown in the accompanying sectional view, are used for annealing rifle parts immediately after forging. The furnaces, two in number, are of the car-bottom type. They are 20ft. long, 12ft. wide, and 9ft. high. The charge to each furnace varies from 20,000lbs. to 40,000lbs., depending upon parts handled.

The surface combustion high-pressure system, it is claimed, inspirates all the air necessary for complete combustion and maintains automatically constant mixture proportions without motors, blowers, or air piping. It is controlled from a central pulpit. A mixture of water and coal gas, averaging 580 B.T.U. per cubic foot, is supplied by the Philadelphia Suburban Gas and Electric Company, Chester, Pa. The gas is delivered and metered under a pressure of 25lbs. The gas is metered by a rotary pressure meter and a Bailey flow meter.

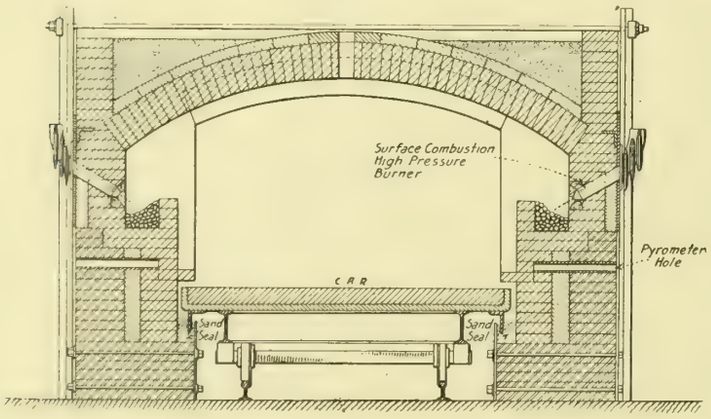
During the heating-up period, each furnace consumes about 10,000 cub. ft. of gas per hour. When temperature has been reached, this is dropped to about 5,000 cub. ft. per hour. For a maximum weight charge, approximately 72,000 cub. ft. of gas is used by each furnace. Two charges per furnace can be secured per 24 hour day. Cost of gas in this case is based

on a sliding scale rate. The approximate average rate for this work is 43 cents per 1,000 cub. ft.

The temperature of the anneal is 1,550° Fah. The time of the operation is as follows: The charge is placed in the cold furnace, fuel is turned on full, until the furnace has reached correct temperature. The time it takes to reach the temperature varies with the weight of charge. For a 40,000lbs. charge, it takes about 5 hours. After the temperature has been reached it is held for 4 hours to allow the heat to soak into the work. After this 4-hour soak, the fuel is turned off and furnace is allowed to cool slowly, the work not being taken out until a temperature of 400° or 500° Fah. has been reached.

A flat car, with a firebrick top, serves as the bottom of the furnace when in place. This car effects a seal with the furnace walls by means of a sand seal. Two cars are used in each furnace, meeting at the centre. Each furnace has two doors which, when closed, rest on top of the cars, the cars themselves extending out beyond the furnace walls about 6in. The cars ride on rails which run right through each furnace and extend about 20ft. beyond in both directions. The cars are handled by winches, and the doors are operated by air hoists.

The furnaces are of the heavy-rail buck-stave type with red brick outside. The firebrick lining is backed up by cork-brick insulation. Heavy tie rods tie the buck staves both across and end to end. To prevent leakage of cold air in, giving an oxidising atmosphere and lowering the furnace efficiency, a furnace back pressure is carried, the flue openings being adjusted to a size to get this condition. The furnaces



SURFACE COMBUSTION ANNEALING FURNACE.

are designed to develop and utilise the maximum possible amount of radiant heat, and the flues are arranged to distribute the hot gases uniformly and to release them at the lowest possible temperature. Each furnace is equipped with 20 surface combustion high-pressure burners.

Both furnaces are controlled from a central control point by a single valve which regulates the pressure supplied. By raising or lowering the pressure, the gas supplied is increased or decreased, thereby raising or lowering the temperature. All pyrometer readings are also taken at this point from a multiple point indicating instrument. Four couples are located in each furnace, one in the centre on each side of each car. A small amount of a man's time suffices to hold the furnaces to the exact temperature called for. The temperature control is found to be accurate.

Readings on an orsat apparatus have shown neither oxygen nor carbon monoxide and an average of 15·2 per cent. carbon dioxide. This shows that there is no excess air and no unburned gases. When the furnaces were first put into operation, it was planned to pack the rifle parts in large steel boxes with covers sealed with clay. This was to prevent oxidation. Believing that an absolutely reducing atmosphere could be maintained, which would produce a minimum of scale, a trial was made, simply stacking the parts, uncovered, on the car top. The trial was successful and the operation has since been handled in this way. To maintain this reducing atmosphere the mixture is adjusted to give a flue gas reading of about 1·2 per cent. carbon monoxide.—"The Iron Age."

CORRECTING TURBINE TEST RESULTS.

BY H. A. COZZENS, JUN.

THE conditions of pressure, superheat, and vacuum determine to a large extent the design of a turbine. The builder is supplied with these data before he undertakes to construct the machine, and quotes the performance in pounds of steam per kilowatt-hour on the assumption that the turbine will operate under the prescribed conditions. It is often of interest to compare the performances of steam turbines when operating under conditions which vary to some degree. If two turbines built to operate under similar conditions are to be compared when the conditions vary, the performance of one turbine must be equated to that of the other or to the individual guarantee of each. The conditions during the test may vary, due to several causes. For instance, one test may be run in January, when it is easy to maintain a high vacuum, since the water is cold; while the other may be run in the summer, and the vacuum fall an inch or more. The vacuum condition has the greatest effect on the steam consumption of the turbine, so that the test made in the summer would show a higher steam consumption than the test run in the winter. Instead of assuming two turbines, it might be desired to compare the tests of the same turbine run at different times.

Again, before a turbine is turned over to an operating company, an acceptance test is usually made. This test is run under operating conditions, and the results equated to the conditions of the guarantee. With large units the tests must usually be conducted in the power station after the unit has been installed, and under conditions that vary to a considerable extent. With large-sized units it is practically impossible to make shop tests as in the case of small units, for several reasons. Among these might be mentioned the necessity for a huge boiler equipment to supply steam for the units, and the practical impossibility of maintaining ranges of pressure and superheat for several units. Again, the question of securing the proper load conditions is one that presents difficulties.

The standardisation of turbine tests is usually accomplished by increasing or decreasing the test water rate obtained by a predetermined percentage for a variation in pressure, superheat, and vacuum from the conditions as stated in the guarantee. This brings the turbine test performance to the same basis as the guarantee, and permits proper comparison of the performances.

TABLE I.—*Corrections to Water Rate shown by Test Data.*

Standard Conditions:				
Steam pressure at throttle	190lbs.			
Superheat	100° Fah.			
Vacuum at turbine exhaust	28·5in. Hg.			
Test Results:				
Pressure	198	194	192	201
Superheat	115	89	93	106
Vacuum	29·4	29·4	29·3	29·2
Test Water Rate:				
Pounds per kilowatt-hour	13·65	13·17	13·52	13·27
Percentage Corrections:				
Pressure	+0·73	+0·36	+0·18	+1·00
Superheat	+1·20	−0·88	−0·56	+0·48
Vacuum	+4·50	+4·50	+4·00	+3·50
Total	+6·43	+3·98	+3·62	+4·98
Correction in pounds	+0·88	+0·52	+0·48	+0·66
Corrected Water Rate:				
Pounds per kilowatt-hour	14·52	13·69	14·00	13·93

The conditions of pressure and superheat do not vary greatly enough in the average power-house to affect the turbine performance to a very large degree. Numerous tests have determined that the corrections for these two conditions should be 1 per cent. for every 11lbs. variation in pressure, and 1 per cent. for every 12·5° Fah. of superheat variation. The correction to be applied for vacuum variation varies from 3 to 6 per cent. at the higher vacuum. Usually about 5 per cent. is taken as the correction factor for each inch variation. In tests where little is known concerning the effect of vacuum on the unit, it is not always satisfactory to assume a certain per-

centage, so that it becomes necessary to run tests to ascertain the precise effect and correction. The usual procedure in such a test is to hold the load steady at three or four points, and operate at vacuums of 28in., 28·5in., and 29in. (corrected to a 30in. barometer) by admitting air into the condenser. From these data the proper correction factor may be obtained. The

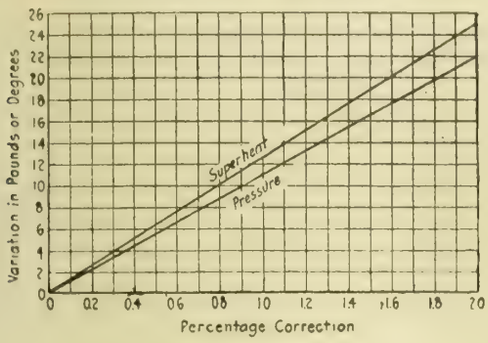


Fig. 1.

corrections are added or subtracted from the steam consumption as obtained during the test, according to whether the operating conditions are above or below those of the guarantee. If the test conditions are above, the corrections should be added.

As a simple example let us consider that the vacuum correction is 1lb. of water for each inch variation. With this as a basis, assume that the guaranteed vacuum is 28in. and the vacuum on the test was 29in., at which point the turbine had a water rate of 14lbs. per kilowatt-hour. Since the test vacuum is greater than the guarantee by 1in., we would add 1lb. to the water rate, making the consumption 15lbs. per kilowatt-hour with a 28in. vacuum instead of 14lbs. per kilowatt-hour as shown by the test.

In order to eliminate the mathematical work in computing corrections to be applied to test results, the curves Figs. 1 and 2 have been drawn, which will serve as models for drawing

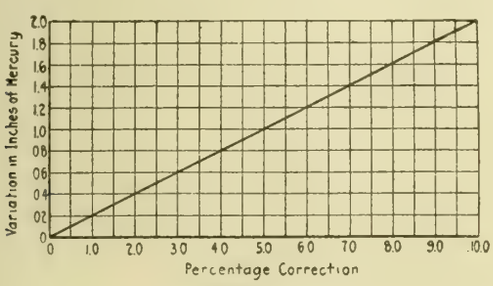


Fig. 2.

curves for various correction factors to suit individual conditions. Table I. is a summary of a turbine test in which the water rate has been corrected by the use of such curves, and shows a convenient form for recording test data when comparisons of the performances of steam turbines are being made.—"Electrical World."

CLEANING SMALL IRON AND STEEL PARTS.

BY E. S. THOMPSON.

Reviewing the past with reference to the plating industry and the methods and processes used, we can but wonder why we were so slow in grasping the opportunities for improvement that were ever before us. The old way of doing things was slow—we must admit that—and far from economical. To say nothing of the rapid plating solutions now used, and adhering strictly to the cleaning of parts preparatory to plating, we could write a small book. It took the outbreak of the European war and the soaring price of chemicals used in the arts to furnish the incentive for cheaper processes and more rapid handling of the work to wrest a profit from the plating-room.

One of the most difficult problems was the cleaning process. The use of mineral oils was resorted to in the manufacture of tripoli, rouge, buffing compositions, &c. It is well known that mineral oils are not easily removed from iron in caustic solutions. This made the cleaning hard to accomplish. It required many hours' immersion of the parts to be plated in the caustic solution, and much mechanical cleaning in the way of scrubbing, and the consumption of pumice stone and brushes. All, including labour, have advanced in price.

It is a hard proposition to prevail upon manufacturers to allow an increase in cost of production in the plating room which will meet the actual increase in cost of labour and supplies. The cost department presents a set of figures to the manager which shows an appreciable increase in overhead and labour. Of course, no explanation goes with it, and it is very often the case that the plater is requested to get his cost down. That is where he needs to be resourceful. He cannot reduce the wage scale, so there must be increased production per man, but he cannot go into the department and drive the men to greater efforts. He can only search his wits for shorter and quicker methods whereby increased production may be had without extra effort upon the part of his help. A versatile man can, in most cases, find processes whereby he can produce at less cost in labour or supplies.

In the matter of cleaning we will consider the electric cleaner. This is a rapid process on larger parts, effectively removing the oils and greases, but it, too, has its drawbacks. It is the most rapid and economical method of cleaning where the operator thoroughly understands the handling of the cleaner, but as unskilled help is usually employed for that work, it is a constant source of annoyance through the peeling of the deposit on the corrosion of the iron to be plated. If the work is cleaned on the negative side of the electric circuit, which is the most effective way of removing the oils and greases, there is usually a deposit of some foreign substance which renders successful coating with nickel or another metal in a cold solution impossible unless the plater knows exactly what he is doing and makes up his solution to a formula which, when the electric element is applied or conducted into it, in its reaction will still hold in solution the metalloids or metals, and refuse to deposit them out, or if deposited out, re-dissolved as fast as deposited. Cleaners of this description are in use, but they are handled by men who know their business, and who do not accept failure as the final word. Then the electric cleaner is well adapted to pieces which may be racked or strung on wires, so that every part may be exposed to the action of the current. Small parts which are best handled in baskets, and mechanical platers, cannot be cleaned conveniently by this process.

It is the small parts which prove tedious and expensive in the plating room. By the old process of cleaning they cost more to prepare for plating than many sell for in a finished state. Cleaning with kerosene, hot water, and acid has been practised by the writer for some time where small parts, such as screws, nuts, bolts, washers, &c., handled in baskets, were to be cleaned. The articles are thrown into kerosene while still warm from the polisher, if possible, and the polishing compounds are dissolved by it in a few minutes. If the parts become cold before immersing in the kerosene it may require two hours or more to remove the polishing composition. It is not necessary to brush them when cleaned in this way. They are then taken from the kerosene and dipped in naphtha, allowed to drip for a few seconds, and then immersed in boiling water. The use of kerosene is recommended for the first immersion because it is not so inflammable as the naphtha, neither is it so volatile, and is used solely for economical reasons. The second immersion in naphtha is because the naphtha is highly volatile under heat, and is easily removed by hot water. When the parts are immersed in the hot water immediately after being taken from the naphtha dip the volatilisation of the naphtha is so great that violent ebullition ensues, and if the operator is not careful he may become scalded by the hot gases coming upon his hands, or by the water itself leaping up to them.

The dissipation of the gases answers the same purpose as the electric cleaner in that they serve to throw off any adhering particles of grease which may be upon the parts. If the work is left in the hot water for a few minutes every atom of the naphtha will have been volatilised, and the work be clean

so far as any grease is concerned. But the heat and exposure to the oxygen set free by the boiling water causes a film of oxide to form upon the parts, and this would render successful plating impossible. It follows then that we must remove the oxide. This is done by a short immersion in a 10 per cent. solution of muriatic acid. When the parts come from this dip they are chemically clean, and will stand the water break test, and may be thrown into the mechanical plater immediately after the acid has been thoroughly removed by rinsing in running water. If the acid dip should be contaminated with copper the film of copper is removed, of course, by immersing for a short period of time in cyanide solution. These operations may be followed so closely, one after the other, that we might say it is a continuous process and the employés will lose no time between operations. The cost of kerosene and naphtha is only about 5 per cent. of the cost of caustics and the acid is almost nothing. The time saved is about 95 per cent. over the saponification process, and the labour saved from the scrubbing process is about 500 per cent., so we see that the work can be produced very economically. A batch of work can be put through the cleaning and plating processes in 45 minutes, where it formerly needed several hours.

Then there is the tumbling in sawdust process to remove the heavy grease, which does away with the immersing kerosene, and is much cheaper than the kerosene where the factory is equipped with a tumbling barrel. This is followed by the naphtha dip and the hot water and acid as above explained, and is equally successful.

There are many ways in which a live foreman can reduce the cost of production, and at the same time keep the quality of his work up to the standard, as well as make the work of his men lighter. In the shop conducted along the lines of efficiency there are very few disputes with the help where good judgment on the part of the men in charge is exercised. A foreman or superintendent should know when his men are producing, and should not drive them every minute of the day.—"Brass World."

Association of Supervising Electricians.—The opening meeting of the new session of this association was held on Tuesday, September 26th, when the president, Mr. A. P. Trotter, M.Inst.C.E., delivered his presidential address, which was devoted to the education and technical training of electrical engineers. We purpose giving an abstract of the address in our next issue. The papers to be read at the forthcoming meetings of the session are as follows: Tuesday, October 31st, "Electric Heating and Cooking," by A. F. Berry; Tuesday, December 12th, "Electric Meters," by J. Rennie, M.I.E.E.; Tuesday, January 16th, 1917, half-yearly meeting and informal discussions; Tuesday, February 27th, "Modern Power Cables," by H. Savage, M.I.E.E.; Tuesday, April 24th, "Wiring Rules of the I.E.E.," by W. R. Rawlings, M.I.E.E.; Tuesday, May 8th, "Motor Control Gear," by J. T. Mould; Tuesday, June 26th, annual general meeting.

Manchester Association of Engineers.—The opening meeting of this association will be held at the Grand Hotel, Manchester, on Saturday, October 14th, at 7 p.m., when the inaugural address by the president, Mr. F. W. Reed, M.I.M.E., will be delivered. The following is the syllabus of the papers to be read during the session: October 28th, "Friction Clutches," by W. G. Gass, M.I.M.E.; November 11th, "The Nile and the Utilisation of its Water," by A. A. Barnes, A.M.Inst.C.E.; November 25th, "Pneumatic Grain-handling Appliances," by Cecil Bentham, M.I.M.E.; December 9th, "Cast Iron: with Special Reference to Engine Cylinders," by J. Edgar Hurst; January 13th, 1917, "The Development of the Manufacture of Steel Castings," by E. F. Lange, M.Inst.C.E.; January 27th, "Steam Turbines for Land Purposes," by H. L. Guy, A.M.I.M.E.; February 10th, "The Bearing of Research Work on Practical Mechanical Engineering," by Alfred Saxon, M.I.M.E.; February 24th, "Some Considerations in connection with Workshop Design and Equipment," by Edmund Simpson; March 10th, "Workshop Precision Grinding," by H. H. Asbridge, M.I.M.E; March 24th, "The Testing of Steel," by H. Brearley.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Apparatus for discharging aerated vapour from steam condensers. Morison. 11860.
Carburetter for internal-combustion engines. Little. 11887.
Transmission of power, especially applicable to vehicles and ships. Thomas. 12949.
Rock drills. Howell. 13142.
Turning lathes. Wade. 13331.
Carburetters for internal-combustion engines. Clough. 13408.
Couplings of railway wagons. Tomkins. 13525.
Signalling mechanism for mines. Mack. 14016.
Safety railway facing points. Woodard. 14197.
Mechanical appliances for loading and unloading coal. Thomas. 14249.
Feed-water heating apparatus for locomotive boilers. Willans, Luard, & O'Donnell. 14976.
Rolling-mill drives. Farwell & Gibbons. 15396.
Laminated springs. Brown Bayley's Steel Works, Ltd., and Sanders. 16450.
Liquid-fuel supply arrangements of internal combustion engines. Doyle. 16746.
Ball and knuckle joints. Page. 17444.

1916.

Power transmission and reversing gearing. Seabury, H. 1580.
Means for supplying air to furnaces for consuming smoke. Jansen, J. Hassel-. 5129.
Screw-cutting lathes. Sundt, A. 5995.
Oil engines. Walker, J. R., and Walker, A. E. 6681.
Furnace fire bars. Bennis, A. W. 7317.
Screw-cutting taps. Housley, R. B. 9351.
Roller bearings for the axles of railway vehicles. Heppell, J., and Dobson, R. G. 10255.

ELECTRICAL, 1915.

Electric signalling apparatus. Mackenzie. 12039.
Arrangement for producing short uni-directed high-tension electric current impulses. Otto. 13129.
Dynamos. Neuland. 13287.
Dynamos. Heys (Neuland Patents, Ltd.). 13480, 13482, 13483, and 13484.
Dynamos of the commutator type. Schroeder. 13561 and 13562.
Telephonic transmitters. Graham. 16207.
Electric switch appliances. Mavor & Coulson, Ltd., and Lawrence. 16502.

1916.

High-tension magnetos. Midgley, A. H., and Vandervell & Co., C. A. 3299.
Dynamos. Neuland, A. H. 5526.

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,, tubes (brazed)	1/6¼ ,,
,, ,, (solid drawn)	1/4¼ ,,
,, ,, wire	1/3⅜ ,,
Copper, Standard	£123/–/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£32/5/– ,,
,, Foreign (soft)	£30/10/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
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,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	32 5/16 d. per oz.
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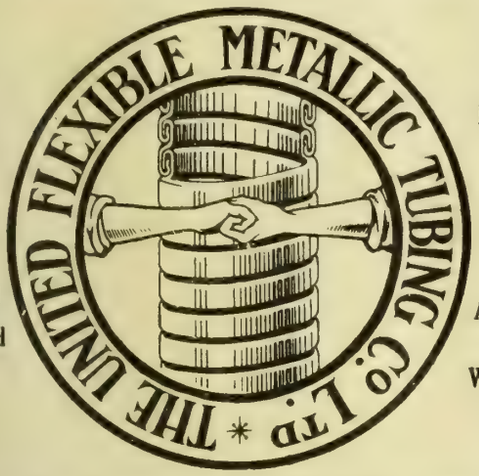

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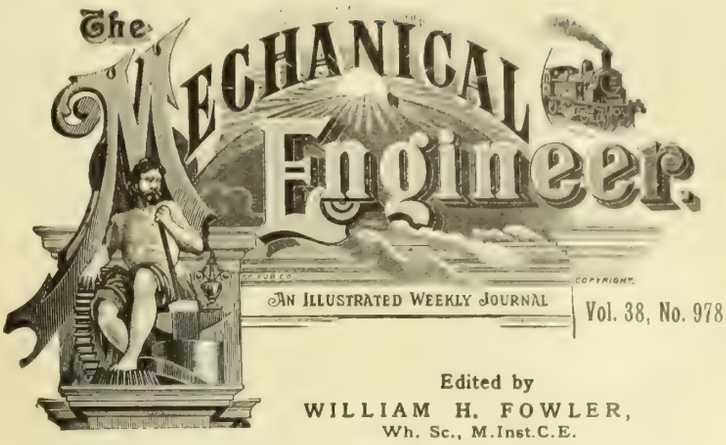

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Uniform Driving in Textile Mills.

In a short note to the Journal of the Department of Textile Industries issued by the Bradford Technical College, Prof. G. F. Charnock draws attention to the effect on output of uniform driving in textile mills. While the importance of the subject is generally recognised amongst textile men, its exact effect on output is not clearly realised, and owing to this lack of perception they are inclined to give credence to exaggerated claims made on behalf of improvements in methods of driving. This is rather surprising, for the arithmetical elements of the question are simple. It is impossible, of course, to secure absolute uniformity of speed by any method of driving owing to the variations in load, and the aim in governing is to make the speed fluctuations resulting from them as little as possible. At the same time there is a maximum speed in spinning and weaving which the material will stand and which must not be exceeded. Obviously, to ensure maximum output it is desirable to approach this critical speed as closely as possible and to make the difference between this maximum and the minimum as small as possible. These are the simple elements of the case, and it is easy, as Prof. Charnock points out, to deduce the effects on output from them. If, for instance, we suppose the variation in speed in the running of certain machinery amounts to 12 per cent., a figure which he says is frequently reached in the case of looms, then the average speed, which will of course measure the amount of fabric produced, will be 6 per cent. less than the maximum, or in other words the driving might be said to have an efficiency of 94 per cent. If the speed variation were reduced from 12 per cent. to 4 per cent., then the output of fabric would only be 2 per cent. below the maximum; that is to say, the efficiency of the driving would be 98 per cent., representing an increase over the previous case of a little over 4 per cent. The gain may not appear

striking, but as it is secured at practically no increase in fixed charges it represents a considerable sum when expressed as interest per annum on capital employed, and is worth the expenditure of considerable effort to obtain. If speed variation could be reduced to 2 per cent. —an attainment scarcely possible of realisation in practice— the average speed would be 99 per cent. of the maximum, and the increase in output as compared with the 12 per cent. variation would be a little over 6 per cent. It will be obvious from this that any claim to effect an increase in output of as much as 30 per cent. in such a case as we have assumed, viz., by diminishing the 12 per cent. variation of speed to 2 per cent., must be fictitious. It is conceivable that such a saving might possibly be effected by a general speeding up of machinery which had been allowed to run at a speed much below the maximum permissible, but this would be independent of any question of speed regulation in itself. It is desirable that the questions of under-speed *per se* and close speed regulation should not be confused. No doubt there are instances in which the machinery might be speeded up as a whole with advantage, but they are comparatively few. On the other hand, there are many cases in which owing to the defective governing the average speed which determines the output might be increased, and though the saving from this may not be sensational, it is one which textile manufacturers ought not to neglect.

MAKING AIRTIGHT ALLOY CASTINGS.*

BY S. D. SLEETH.

BRASS and bronzes are recognised as metals adapted especially to withstand internal air pressure, and this paper will, therefore, be confined to the use of such alloys. Density and strength are the two qualities that go to make up a metal suitable for the retention of air or other gases under pressure, and while strength may be secured through proper design, density is that elusive will-o-the-wisp which we chase for a while in one direction and think we have captured, only to find that it has eluded us and we must look for it elsewhere. This leads us then to the conclusion that there can be no hard and fast rule whereby this desirable quality of density can always be obtained, probably because of the fact that there are so many variables that enter into the process and that they cannot always be under our control. To enumerate some of these variables, we have the design of the article to be cast, the design of the pattern with reference to its position in the flask, the composition of the alloy, the treatment of the metal in the furnaces, and the temperature of the metal when being poured. Each item in this list is worthy of extended discussion, but time will not permit of more than a cursory glance at each subject.

We shall begin with the design of the article to be cast. This has a very important bearing upon the ultimate success of the casting. The designer should bear in mind the desirability of having all cross sections of approximately equal thickness in order to prevent draws at heavy portions. If this is not possible, access to all large sections should be allowed for the use of chills to prevent such draws. If the cored cavities are large the cores will, themselves, act as chills. Fillets should be as small as possible in order that excessive masses of metal shall not be concentrated at one point.

In laying out patterns, the patternmaker must be governed by several things. He must know what chills are to be used so that large chilled surfaces may be placed in a vertical position in order to prevent the metal kicking off these surfaces. He must know what parts are to be clean, such as valve seats, &c., and to what parts loose sand may be allowed to flow if any be found in the mould. Such unimportant parts should be placed high in the cope and the loose sand will flow to them on top of the metal. A clean mould, however, is absolutely essential to good tight castings. An exceptionally clean casting may be obtained by gating it from another casting which will itself take all the dirt.

On the use of chills, the following may be taken as an almost universal law: Use chills on all enlarged sections in close proximity to smaller sections and connected thereto. If the sections are exceptionally large, use a sinking head on top of the large sections. Gate your moulds with a heavy upright pouring gate as near to the pattern as possible. The gate leading from the pouring gate to the pattern should be made large at the pouring gate and then reduced sharply into the pattern. If it is large where it joins the pattern, in all probability it will show a draw in the casting at the gate. As a rule, it is better to gate in a light part of the casting than in a heavy portion. If a sinking head be used it should be placed on the heavy part.

As regards the alloy to be used, the following compositions have been tried and found satisfactory for the purpose of making the desired castings:—

Metals	No. 1 alloy. Per cent.	No. 2 alloy. Per cent.	No. 3 alloy. Per cent.
Copper	72·50	82·00	83·00
Tin	1·75	7·50	11·50
Zinc	19·25	4·75	4·00
Lead	6·50	5·75	1·50
Total	100·00	100·00	100·00

No. 1 alloy is used for ordinary castings, such as cocks, pistons, bushings, &c. This alloy is easily machined, but is not intended for use with very high pressures. No. 2 and No. 3 alloys are intended for use with high pressures, and are harder to machine in proportion.

As might be expected, the treatment of the metal in the furnaces is of vital importance. If proper allowance for oxidation of zinc, &c., is not made, the alloy intended will not be produced. Furthermore, the metal must be taken from the furnace as soon as it reaches the proper heat, for if allowed to soak in the furnace, it will take up gases, and the castings made from it may be porous. In certain packing ring mixtures, we consider this item so important that we use an alarm clock to ensure the metal being poured off at exactly the proper moment.

The temperature at which the metal should be poured into the moulds is important, and no doubt many castings are lost due to carelessness in this matter. If poured too cold it is almost impossible to obtain solid castings, especially at the gate. On the other hand, if poured too hot, the castings may be porous throughout. Great care must be taken to see that no aluminium gets into the mixture, as a very small percentage of it will cause the castings to leak. Antimony and iron will do the same, but not to so great an extent. Aluminium has a very peculiar action on the metal. The castings will look solid and will not show a draw, but when put under pressure will leak all over. It is one of the most dangerous metals around the brass foundry. Antimony does not act as quickly as aluminium, but has about the same effect if used long enough in the mixture. You may start out with a small percentage and it seems to do no harm, but if used until it is mixed with all returned material, such as turnings, gates, &c., the castings will become porous.

In conclusion it may be said that solid castings of a density to withstand air pressure can be obtained only by the exercise of the greatest care from the design of the article to the pouring of the metal into the mould. Even then failures will sometimes happen, and final success can be obtained only through experiment and the adaptation of the various methods to the article under consideration.

* Paper presented at the annual meeting of the American Institute of Metals, September 11-15th, 1916, Cleveland, O.

"Refractories."—The Faraday Society will hold a general discussion on "Refractories" at a meeting, provisionally fixed for Wednesday, November 8th. The discussion will be presided over by Sir Robert Hadfield, F.R.S., and the opening paper will be read by Dr. J. W. Mellor, of Stoke-on-Trent. Suggestions are invited from those specially interested in the subject as to any particular aspects which they would like ventilated or discussed, and those who are desirous of contributing to the discussion or who wish to show any exhibit at the meeting are invited to communicate with Mr. F. S. Spiers, Secretary of the Faraday Society, 82, Victoria Street, Westminster, S.W.

REDUCING FOUNDRY COSTS BY ANALYSIS.*

BY R. E. KENNEDY.

The successful foundry operator knows that efficiency begins at the top and works down that efficiency in the shop is the result of efficiency in the office. He knows that the best materials, the most effective methods, and an organisation of skilful workmen do not just happen. On the contrary, he realises with the keenest appreciation that these things follow only upon the dictation of the directing forces. Foundry operation, like practically all manufacturing, is a problem involving three factors, viz., labour, material, and equipment. Each of these factors presents its own special problems, but as they are distinct in character, control is accomplished in a simple manner by dividing responsibility among members of the supervisory staff according to fitness and experience. No one man can be an expert in all lines, and it is not good practice to shoulder upon one man a large variety of duties that he is not fitted to carry. Modern organisation calls for specialists—each supreme in his own special field. Such a plan centralises responsibility in the hands of thoroughly competent men, who reduce costs by eliminating waste.

A critical examination of the principal operating factors should be the daily programme of the foundry manager. A few hints as to the direction which this examination should take are indicated hereafter. We will take up a discussion of each of the three factors in the order of what we consider to be their importance. Labour is considered to be the most important because, without the right kind of labour and its proper supervision, good material and equipment would go for naught.

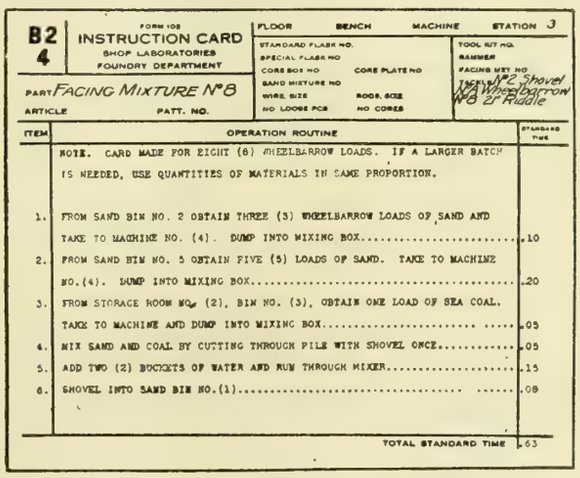
You will often see two factors, situated almost side by side, manufacturing the same line of goods, with the same kind of equipment—yet the quality of the work will be vastly different. The difference will almost invariably be traced to workmen, but the blame will have to be placed on the foreman or superintendents, for the workmen will produce the quality of output demanded of them or, if they do not, the right executives will either train their men to do better work or eliminate them and get others who will. Where slipshod work is tolerated, there you will find a tendency for all the workmen to turn out slipshod work, and when the best is demanded, you are sure to find the best. The whole question then of quality of output rests practically altogether with the management.

It behoves the management, therefore, to be strict in its demands and always on the look-out for ways and means of keeping the quality and quantity of the product as near perfection as it is possible to go. The maintenance of labour standards means a constant study of men and their methods of doing the work they have been given to do. It is well known that there are many ways of doing any one piece of work, but many forget that there is only one best way, and no one has yet put into practice that best way. A few seem to have reached this best way, but the greater majority, while still far from the goal, are content to rest on their oars, and follow the method taught them a long while ago.

In foundry work there is no general way of determining whether the method in use is the best, and the common thing to do is to put a man on the job and let him go to it, the amount of advice given him being very small compared with the amount of valuable instruction which could be given. The changing of methods is, as a general rule, a slow process of evolution, the changes being suggested from time to time by certain circumstances brought to light mostly by chance. During recent years, due to the change of work and competition, it has been necessary for many shops to make thorough analyses of their operations to hasten improvements in methods and equipment. For these analyses, time and motion studies of the different classes of work have been made, and it has been found that such a study, scientifically conducted, shows up the following factors: (1) The improvement that can be made by the management in the conditions, equipment, and shop organisation to help the operator improve the quality and increase the output of his work. (2) The work done by the operator which is unnecessary, and by eliminating which the operator can turn out more product of as good a quality in the given time, without any more exertion.

Time study, when rightly applied, means the hastening of these changes because of the facts brought to light by scientific study of the conditions. These studies should be made by some one familiar with the local shop methods, familiar with the best practices in this line of work in other shops, and one who will not let himself be held to the traditional shop method just because it had been customary to do the work in one certain way in the past. Also, changes must not be made just because they have been made in other shops, but a careful detailed analysis of all the work being performed in the shop must be made, and after thorough study of the probable results it is determined whether the changes will benefit the shop.

In considering the materials used, the foundryman will first have to investigate his needs thoroughly. The question will have to be asked concerning each material item, "What is the real need in this case?" It might be possible to entirely eliminate the blackening of cores in certain cases if the sand were changed. Is the moulding sand used giving as good results as that used by the most successful foundries in this line of work? Perhaps the castings would be selling better if a sand giving a smoother surface were used. Very often the core sand in question is being used because it has been customary to use it in past days, and no one has suggested a change, or perhaps it is a cheap local sand, and the foundryman hesitates about paying more for a sand from a distance. In one large foundry the coreroom foreman found that he was



B2 4 — FORM 108 — INSTRUCTION CARD — SHOP LABORATORIES — FOUNDRY DEPARTMENT

FLOOR | BENCH | MACHINE | STATION 3

STANDARD FLASK NO. | SPECIAL FLASK NO | CORE BOX NO | CORE PLATE NO | SAND MIXTURE NO | WIRE SIZE | RODS, SIZE | NO LOOSE PCS | NO CORES

TOOL KIT NO. | HAMMER | FACING MIT NO | TOOLS: No 2 Shovel, No 8 Wheelbarrow, No 8 2" Riddle

PART: FACING MIXTURE No 8 | ARTICLE | PATT. NO.

ITEM	OPERATION ROUTINE	STANDARD TIME
	NOTE. CARD MADE FOR EIGHT (8) WHEELBARROW LOADS. IF A LARGER BATCH IS NEEDED, USE QUANTITIES OF MATERIALS IN SAME PROPORTION.	
1.	FROM SAND BIN NO. 2 OBTAIN THREE (3) WHEELBARROW LOADS OF SAND AND TAKE TO MACHINE NO. (4). DUMP INTO MIXING BOX	.10
2.	FROM SAND BIN NO. 5 OBTAIN FIVE (5) LOADS OF SAND. TAKE TO MACHINE NO.(4). DUMP INTO MIXING BOX	.20
3.	FROM STORAGE ROOM NO. (2), BIN NO. (3), OBTAIN ONE LOAD OF SEA COAL. TAKE TO MACHINE AND DUMP INTO MIXING BOX	.05
4.	MIX SAND AND COAL BY CUTTING THROUGH PILE WITH SHOVEL ONCE	.05
5.	ADD TWO (2) BUCKETS OF WATER AND RUN THROUGH MIXER	.15
6.	SHOVEL INTO SAND BIN NO.(1)	.08
	TOTAL STANDARD TIME	.63

Fig. 1.

enabled to entirely eliminate the use of core dryers by using a different sand.

Are the binders used really the best for the purpose of the shop or quality of casting to be produced? The use of an oil binder with an open sand frequently will do away with all venting. The writer remembers a particularly striking example of unnecessary venting which was due to lack of knowledge. In a foundry, supposedly modern, a binder was being used on certain water-jacket cores, which made it necessary for the coremaker to spend 20 minutes venting each set of cores. The binder was changed to an oil compound and quartz sand mixtures which, though slightly more expensive, saved more than twice the entire expense of the binder by eliminating the venting. At the present time, many coremakers are spending needless time venting certain oil cores, because no one in the foundry has taken the trouble to ascertain whether the venting can be done away with.

In other cases, a different sand and binder frequently does away with the use of driers or will give more perfectly-shaped cores. The best foundry practice is to use just enough core binder to hold the core sand together until the casting has set. If too much is used, the hard core requires extra work to remove it from the mould, therefore the proper mixtures for different-sized castings and kinds of metal should be determined. The shops which do not have their sand mixtures standardised are the most frequent losers because of excessive binder.

The lack of enough binder and the subsequent loss of cores in handling is also due to failure to standardise the mixture.

* Paper read at the American Foundrymen's Association convention, September 11th to 15th, 1916.

Using the best binder and sand, mixing them in the same way each time, and baking them under the same conditions will produce the results wanted. Core-sand and facing-mixture standards are placed on cards, as shown in Fig. 1.

In the case of cupola supplies, it is a question of obtaining cupola blocks and clays of the best quality, for here, as in nearly all other cases connected with the purchase of materials, it is a paying proposition to get the best. The money saved by the use of inferior, cheap grades will be more than offset by the expenditure of money caused by the amount of extra labour used in relining the cupola at more frequent intervals. Some systems, such as the material record shown in Fig. 2, can be used not only for keeping track of the amount of material on hand, but has a place for the

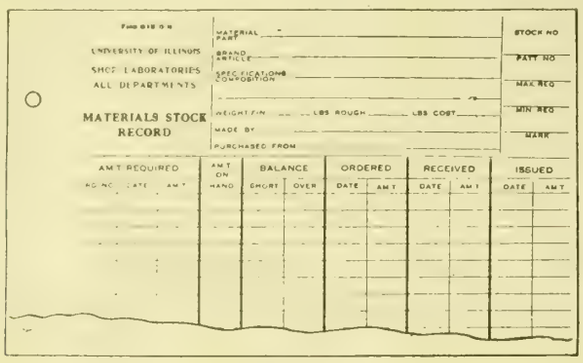


FIG. 2.

entry of a specification for the buying. With this specification, made out according to the best information obtainable, the materials should give satisfaction. The writer has found it to be common foundry practice to order minor foundry materials without any specification as to quality, which is as bad as a similar practice of ordering pig iron without specifying the chemical content.

Moulding sand is another material to which a lot of thought should be given. Many foundries are purchasing the same kind of sand from year to year without really knowing whether it is the best and cheaper when everything is considered.

It is very desirable that foundrymen keep a record of the weight of castings produced for each ton of sand used. Are many castings being lost by scabbing, which would not occur by the use of a different sand? We all acknowledge that the best of moulders can produce castings using any old sand, but does not the less skilled moulder or machine hand have more trouble with scabbed castings? Changing the moulding sand has often reduced the loss of scabbed castings, turned out by semi-skilled moulders, to a minimum. It takes only a few bad castings to make some apparently cheap sands very dear in cost.

The necessity for giving strict attention to the purchase of materials cannot be given too much emphasis, for materials that require extreme care in handling will require very skilled men in their manipulation, and skilled labour costs more than unskilled. We do not think anyone will advocate the use of this kind of material when castings of as good a quality can be produced at less cost by using cheaper material and labour. In these days when inexperienced men have to be used, it is a better policy to place in their hands such materials as he can work with satisfactorily with the assurance that they will produce good results. From this can be seen the importance of having men at the head of the shop who are skilled enough, and who will analyse the results and can place the blame where it belongs.

Once when the writer was working as a coremaker in a large engine plant, many small castings of a certain type were lost, and the foreman of the foundry claimed that the cores blew. The coreroom foreman, not knowing much about moulding, had to take his word for it, but the writer investigated the case, and found out that the castings did not have a head of metal high enough to force and hold iron in the projecting part. The moulding practice was changed. The foundry foreman either did not know enough to analyse the cause or, not caring to take the blame, tried to make the coreroom foreman the goat. This habit of always trying to place the blame on the other man, thus dodging personal responsibility, is one of the worst faults of most foundrymen, as well as men in other lines of work. The organisation of an efficient inspection department with men having a good knowledge of foundry practice will eliminate these troubles by carefully analysing all losses.

In the matter of equipment, much has been done in the last few years to improve foundry conditions through the application of moulding machines, sand-cutting and mixing equipment, and transportation and conveying systems, and most foundrymen have taken advantage of some or all of these means to increase their output. These devices all require considerable outlays of money, and before making an installation, a study should be made of the advantages to be gained, determining what machine will best fill the particular needs at hand. In most cases, the answer is determined by the number of castings to be made from different patterns. Those machines which are simple and permit of easily-changed patterns are of most value to ordinary shops. Among such machines are the ordinary hand or air squeezer, the simple roll-over drop plate, and the straight stripping plate machine. Very few foundries are doing work of such a nature but that it will pay them to investigate the possibilities of installing some of the simpler moulding machines. In foundries having exceedingly large orders, the more complicated machines that combine several operations and the installation of elaborate sand-handling plants are important factors.

Nearly every shop will find that it pays to have simple electric riddlers and sand mixers, for these machines will supply the moulders with a thoroughly riddled sand and facing at a great saving in labour. Also there is a saving in the amounts of sea coal and core binders used, as compared with hand-riddled sand. The use of these mixtures will assist the foundryman in standardising his methods of mixing. It certainly is surprising how often we still meet foundry foremen, who, without giving the matter real thought, declare that such machines are no good, believing they know it all, and not caring to have others teach them anything.

It is also necessary, in order to get real value out of machines, to keep them in use and not let them lie idle any more than is absolutely necessary. An example of the losses accruing from idle machines was found in the foundry of a well-known automobile factory. There were six moulding machines in the brass department, which were used merely as ordinary moulding benches with vibrator attachments.

STANDARD TOOL LIST 11
INSTRUCTION CARD NO. D1

	Rack	Sec	Shelf
Set Std floor tools	2	D	43
20 Wedges	1	A	6-24
2 Gate pins 30"	2	D	42
3 Riser pins 4"x 20"	1	B	30
20 d spikes	2	C	15
1 Lb. 3 d nails	2	C	18
4, 8" Roll-over clamps	4		3
6, 24" Clamps	4		5

FIG. 3.

Although most of the work in this department was of a type almost ideal for squeezer machines, it was not fitted up on plates for use on these squeezing machines. There were 20 other machines in the grey-iron department of this shop stored, or rather dumped, in storage bins, and only two machines were in use on the cylinders, although good use was being made of rock-over machines for core work. The difficulty seemed to be that the foreman, having a little trouble in getting the squeezing machines and plates fitted up as they should be, got disgusted and turned back to the old way of doing the work. Where possible, the make of machines should be kept as uniform as possible, for this means fewer kinds of pattern fixtures, greater interchangeability of work, and all machines in use all the time.

Another important item to consider in foundry equipment is that of flasks. In only a few cases do the old wooden flasks pay, for their weakness and short life make them the most expensive in common use. It is up to the foundry manage-

ment to decide whether they want steel, iron, or wood flasks, and careful consideration should be given to finding out what is best for any particular shop. The question of investment, absolute accuracy of flasks, ease in handling, standardisation of pins, and length of service, are some of the things to be considered by the foundryman in studying this vital item. The foreman who is a constant reader of foundry literature, learning of the kinds of new equipment being put on the market, is the one who is most apt to keep his shop on the best paying basis. The one who merely stays in his own shop, without seeking outside information, is the man who lets the world march on, and then suddenly wakes up to find himself out of the running.

The proper equipment having been installed, it is necessary to watch closely and have it always in running order. Flasks and boards should always be kept in shape, and all repairs should be made as soon as possible. To be sure that this is done, it will pay to have some one man charged with the upkeep and make him responsible. Moulders, coremakers, and other foundry help, as a general rule, know very little about the proper care of machine tools, and cannot be depended on to see that the mechanical equipment is cared for in the proper way. Because so many foundrymen lack this training in machinery upkeep is all the more reason for having some machinist whose sole duty it is to keep the mechanical equipment in the best of condition. We all know that good machinery in good condition is one of the best paying propositions in any line of manufacture, and good machinery neglected is one of the most costly items in a shop, for it is money being thrown away recklessly. Very few foundries have even a semblance of a toolroom, and yet the slogan, "The right tool in the right place when wanted," could be of value to every foundry, as it is to practically all machine shops. Almost every person who has worked in foundries has seen the constant hunt for such tools as levels, hatchets, trammel points, special clamps, gaggers, and many times for decent riddles, rammers, shovels, and many of the most common tools.

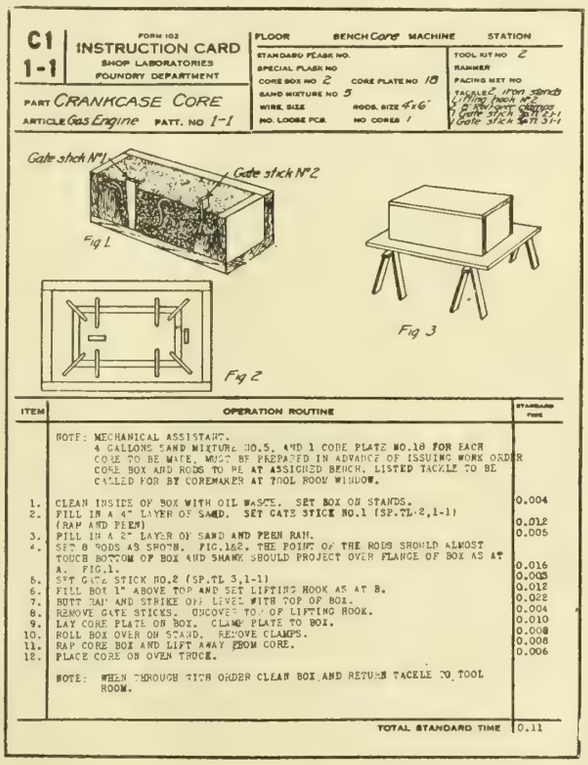
A moulder, when first starting to work in a shop, usually brings in a few tools of his own, and inherits from the man who previously worked his floor some old tools, such as a shovel, a rammer, gate pins, &c. Each moulder is generally fighting to retain possession of sufficient gaggers, clamps, and wedges for his own needs, and frequently has to use makeshifts. Usually, when he is through using clamps and special equipment, he will hide it away for future use, and if, in the meantime, another man has need for it, it cannot be found. What moulder, coremaker, or foundry labourer would not appreciate a good toolroom and a storage place where tools and equipment could be obtained when needed?

With a central storage place, tools and equipment can be kept in repair and on hand in sufficient quantity for the needs of the shop. When a workman is through with special equipment, such as gaggers, clamps, riser pins, blocks, &c., it could be returned by some one whose duty it is to collect such things. Other tools, such as the more valuable special lifters, wrenches, levels, hammers, &c., could be checked out on the ordinary checking system. Even in highly specialised shops there is need of a central toolroom, together with supervision over the tools used, for very few moulders really analyse their needs to the best advantage. Much time could be saved if all the workmen were supplied with the best small tools for their class of work, for there are few foundries in the country where there is not seen a great variety of swab pots, lifters, slicks, vent wires, gate cutters, draw screws, &c. In this large variety of tools there are many which are inefficient and should be discarded. In foundries with a great variety of work, the need for a toolroom for the storage of the great variety of special equipment used is much greater, and it is just as bad practice for a foundry to not have such a place as it is for machine shops to have no storage-room for their jigs, fixtures, and small tools.

It is becoming more and more impressed on foundrymen that before a piece of work is turned over to the workmen, it should be carefully considered by a planning department to see the proper flasks, boards, rods, gate and riser pins, facing sands, and methods of making are placed in the hands of the moulder before he starts to work. This idea may be carried out further by having this information placed on a form and filed away for future use. This record will be of invaluable assistance to those having charge of the planning in the shop. Fig. 3 illustrates a tool card that can be used to advantage by any foundry. Fig. 4 shows an illustration of an instruction card for use in coremaking and coremoulding.

To make such a scheme effective, organisation of the shop forces is necessary, so that when an order reaches the foundry office, the production manager can turn the information, as to when and where the work is to be made, over to the mechanical supervisor. Then from the tool cards, the mechanical supervisor finds out what is needed for the work in the way of tools and equipment, and has everything ready to start work at the proper time, without the necessity of having the moulder or coremaker loaf around while some needed equipment is being found or made. Such a system also avoids having to hunt for some missing part or tool.

When a foundry is in difficulties from the manufacturing end, the solution can nearly always be found from a study of one or all of the three factors which have been discussed. These factors having been analysed in the light of the best in the foundry world, the causes of poor results should be ascertained. Knowing where the trouble lies, it is generally a comparatively easy matter to remedy the cause, but the remedy cannot be applied before the cause of the trouble is located.



C1 1-1 — FORM 102 — INSTRUCTION CARD — SHOP LABORATORIES FOUNDRY DEPARTMENT

PART CRANKCASE CORE — ARTICLE Gas Engine — PATT. NO 1-1

FLOOR — BENCH Core — MACHINE — STATION

STANDARD FLASK NO. — SPECIAL FLASK NO — CORE BOX NO 2 — CORE PLATE NO 18 — SAND MIXTURE NO 5 — WIRE SIZE — RODS, SIZE 4x6' — NO. LOOSE PCS. — NO CORES 1

TOOL KIT NO 2 — RAMMER — FACING MIX NO — TACKLE 2 iron stands, 1 lifting hook No 2, 2 pr. hoist clamps, 1 Gate stick No 1-1, 1 Gate stick No 3-1

ITEM	OPERATION ROUTINE	STANDARD TIME
	NOTE: MECHANICAL ASSISTANT. 4 GALLONS SAND MIXTURE NO.5, AND 1 CORE PLATE NO.18 FOR EACH CORE TO BE MADE. MUST BE PREPARED IN ADVANCE OF ISSUING WORK ORDER CORE BOX AND RODS TO BE AT ASSIGNED BENCH. LISTED TACKLE TO BE CALLED FOR BY COREMAKER AT TOOL ROOM WINDOW.	
1.	CLEAN INSIDE OF BOX WITH OIL WASTE. SET BOX ON STANDS.	0.004
2.	FILL IN A 4" LAYER OF SAND. SET GATE STICK NO.1 (SP.TL-2,1-1) (RAM AND PEEN)	0.012
3.	FILL IN A 2" LAYER OF SAND AND PEEN RAM.	0.005
4.	SET 8 RODS AS SHOWN. FIG.1&2. THE POINT OF THE RODS SHOULD ALMOST TOUCH BOTTOM OF BOX AND SHANK SHOULD PROJECT OVER FLANGE OF BOX AS AT A. FIG.1.	0.016
5.	SET GATE STICK NO.2 (SP.TL 3,1-1)	0.003
6.	FILL BOX 1" ABOVE TOP AND SET LIFTING HOOK AS AT B.	0.012
7.	BUTT RAM AND STRIKE OFF LEVEL WITH TOP OF BOX.	0.022
8.	REMOVE GATE STICKS. UNCOVER TOP OF LIFTING HOOK.	0.004
9.	LAY CORE PLATE ON BOX. CLAMP PLATE TO BOX.	0.010
10.	ROLL BOX OVER ON STAND. REMOVE CLAMPS.	0.008
11.	RAP CORE BOX AND LIFT AWAY FROM CORE.	0.008
12.	PLACE CORE ON OVEN TRUCK.	0.006
	NOTE: WHEN THROUGH WITH ORDER CLEAN BOX AND RETURN TACKLE TO TOOL ROOM.	
	TOTAL STANDARD TIME	0.11

FIG. 4.

It is necessary, to get the best results, to take action along the following lines: (1) Study the methods in vogue in the shop in question; (2) study the methods in vogue in the best practice in this line of work, or any other line of work which might suggest ideas; (3) clean up the shop and arrange it for the best work, providing storage places for equipment and materials; (4) standardise materials, mechanical equipment, methods, and times of operations; (5) route and dispatch work through shop under these improved conditions.

By standardisation, we do not mean that one certain method or piece of equipment should be selected from the many and then adhered to religiously for ever, but we do mean that the best known way should be found and then used as a standard, while a constant search is being carried on for a better standard. We all know that standards are being raised all the time, and are expensive to change, therefore the firm which can set its standard further in advance of the others will find it unnecessary to change the standard as often as the others. Also, it is well known that those manufacturers having a definitely outlined course of procedure will almost always succeed, when often they would fail under the old hit-or-miss system.

The larger and more specialised foundries have had most of these ideas of standardisation forced upon them by the hard

school of experience. They have been compelled to use comparatively unskilled help, and have been obliged to train this help in the execution of specialised tasks, such as machine moulding, sand mixing, pouring metal, &c. Before much can be done in the way of planning and dispatching work through a foundry, the average shop will have several important things to do. First, it will have to be cleaned up. Get rid of the accumulated junk so often found in corners, gangways, and bins. Storage places will have to be provided for all equipment and materials, and methods devised for keeping track of this stored equipment and materials.

These storage places should be arranged in the most accessible places, with men in charge to see that the equipment and materials are kept in their proper places. The arrangement of the foundry should be such that the work proceeds in a steady flow from the raw material yard, through the core and moulding-rooms to the cleaning and shipping departments. With the shop in good condition, an effort can be made to standardise the operation routines and set rates on the different pieces, with some assurance that the rates will be correct. These rates should not be set by estimates by the foreman, but should be made by time-study averages. It is true that the average foreman's estimate of the time needed to do a given piece of work is seldom accurate. When all operations are proceeding in good form, it still remains for the manager and all men working under him to strive constantly to improve methods and results, for the manufacturing world is continually moving ahead, and those who stand still are soon out of the running.

THE PRESENCE OF ALUMINA IN STEEL.*

BY GEORGE F. COMSTOCK.

In the literature dealing with inclusions in steel there are but few references to alumina. One of the earliest of these, and also the most definite, is in an article by Heyn and Bauer, entitled "Kupfer, Zinn, und Sauerstoff," published in the "Zeitschift fur Anorganische Chemie," 1905, No. 45, page 63. This reference to alumina, freely translated from the German, is as follows: "The film-like enclosures of tin oxide in bronzes bear much similarity to the enclosures in mild steel which have been deoxidised with aluminium instead of manganese. A photomicrograph shows such enclosures, which consist, as found by analysis, of alumina. Also, in copper-magnesium alloys similar enclosures can be observed which are due to thin films of magnesium oxide."

Referring to the use of aluminium as a deoxidiser, and the resulting formation of alumina, Dr. Walter Rosenhain, in his "Introduction to the Study of Physical Metallurgy," page 153, writes: "A more powerful deoxidising agent than manganese is furnished by aluminium, but this differs from manganese in two vitally important respects. In the first place, the oxidation product of aluminium is a particularly refractory substance, alumina, which has a strong tendency to remain in the molten metal in suspension as fine particles. These, of course, tend to lessen the strength and toughness of the alloy."

In a paper entitled "The Solid Non-metallic Impurities in Steel," published in the "Transactions" of the American Institute of Mining Engineers, Vol. XLI., pages 803-822, Henry D. Hibbard writes, in part, as follows: "If other elements have been added, such as aluminium, chromium, or vanadium, their oxides and silicates may be present. . . . The too-plentiful use of aluminium in steel may have been condemned, partly at least, because it forms oxides or silicates in the metal, which, being insoluble, and infusible, exist in the solid steel as very harmful sonims. Of course, to form the oxide there must still be some oxide of iron or manganese in the steel. If the metal were free from oxygen perhaps the weakening effect of aluminium . . . would not occur."

The various writers quoted above unmistakably recognise the existence of alumina as a frequent non-metallic impurity in steel. They are aware of the potential harmfulness of this impurity, but they do not give any idea as to how it may be recognised and identified in metallographic work. To supply this deficiency was the object of the author's article on "Alumina in Steel," published in "Metallurgical and Chemical Engineering," December 1st, 1915. This article described the experiments made to ascertain the characteristic appearance of alumina in steel, and showed numerous photomicrographs to illustrate it. The work will not be gone over in detail here, as the original article can easily be referred to.

The differences between inclusions of alumina and ordinary slag or silicates in steel are: (1) Silicate inclusions will generally take a fairly smooth polish in a section prepared for microscopic examination, while alumina is very hard to polish without pitting. (2) Silicate inclusions are always elongated in the direction of rolling or forging, while alumina particles are not. The groups of particles are, of course, elongated, but not the particles themselves. (3) Silicate inclusions are often found of quite large size, as well as very small, while particles of alumina are always small, and do not seem to coalesce into large bodies even when closely grouped together. These characteristics of alumina inclusions agree with what is known of the properties of alumina. Its great hardness and brittleness would account for the pitting effect: its infusibility would account for the small size of the particles and the tendency not to coalesce; and both of these properties together would account for the particles not being elongated by forging or rolling of the steel in which they are embedded. My former article pointed out that no other substance was known that had exactly the same appearance as alumina in a polished steel section, and this statement still holds true.

The well-known metallographist, Prof. Albert Sauveur, of Harvard University, has recently completed an independent investigation dealing with the occurrence of alumina inclusions in steel, in the course of which he examined some of the author's specimens as well as some that he himself prepared. His report of this work was published in the August 1st, 1916, issue of "Metallurgical and Chemical Engineering." The conclusion reached by Prof. Sauveur was that "alumina inclusions may be distinguished under the microscope from the other inclusions generally occurring in steel, being characterised by their small size, their dark coloration, and more especially by a complete absence of elongation in the direction of the rolling or forging.'

It may seem that the characteristic appearance of alumina inclusions, as compared with slag or silicates, is only exhibited in worked steel, but this is not the case. The identification of alumina in cast steel calls for more care and experience than in worked steel, for small silicates here exist as globules instead of fibres, and might perhaps be mistaken for alumina if carelessly polished and examined. But the very dark colour of alumina, its rough appearance and the pitting effect, and the invariably small size of the individual particles are sufficiently distinctive characteristics to enable it to be recognised in castings as well as forgings, especially if the observer is careful and already familiar with its appearance. The usual aspect of alumina in cast steel is the same as in forged or rolled steel, with the single exception that when the particles are grouped closely together in certain spots, these groups are of irregular or rounded shape in castings, instead of being elongated into streaks as in a rolled bar. A similar difficulty to that experienced in castings may be encountered in cold-worked steel, such as wires, tensile test bars after pulling, &c. Here the slag or silicate fibres are usually broken up into fragments and drawn out into streaks, but if carefully polished the fragments of silicates can be recognised by their definite and angular outlines and their smooth surface, while alumina particles will be rougher, probably more or less pitted, and less distinctly outlined.

It is not desired to give the impression that alumina always exists in steel in the form of large groups of particles. Its most usual mode of occurrence is probably in isolated particles, thinly scattered through the metal, and in this form it is practically harmless. The danger in its use as a deoxidiser lies in the fact that with our present knowledge, or under present mill conditions, we can never be sure that the alumina particles will not segregate or gather together in certain parts of the casting or ingot. When this happens the results are dangerously weak streaks. Such streaks may not be common, but they nevertheless do occur when alumina is used, and may cause great harm.

* Abstract of paper read at the annual meeting of the American Foundrymen's Association, Cleveland, September 11th to 15th, 1916.

STARTING DIESEL ENGINES WITH LOW COMPRESSION.*

BY PROF. W. H. WATKINSON.

IN engines of the Diesel type, air flows into the cylinder during the charging stroke, and the fuel oil is not sprayed into the cylinder until the compression has been completed. In order that the temperature of the air may be raised during compression to the ignition temperature of the oil, the compression pressure is usually about 460lbs. to 500lbs. per square inch, and it has hitherto been believed that this high compression pressure was necessary to effect self-ignition of the oil sprayed into the compressed air.

Fig. 1 shows the normal form of the indicator diagrams obtained from engines of this type. During the normal working of these engines the compression pressure is, approximately, the maximum pressure of the cycle; but during the starting of these engines explosions occur within the engine cylinder, and the pressure attained during these explosions may amount to 800lbs. per square inch or more.

Fig. 2 shows a series of starting diagrams, from a 50 b.h.p. engine, which illustrate this point. The pressure attained in the first explosion is 800lbs. per square inch above atmospheric pressure, and considerably higher pressure has been recorded during starting under normal conditions.

On account of the high pressures developed during the starting of these engines, and also because of the higher pressures than those mentioned which are liable to be developed under certain abnormal conditions, it is necessary to make various principal parts of the engine much stronger than would be necessary for the normal maximum working pressure and, in consequence, these engines are heavier and more costly per unit of power than other types of internal-combustion engines. The author has found that it is possible, in several different ways, to obtain ignition temperatures during compression without the use of high compression pressures, and the object of this paper is to describe the simplest of these.

Fig. 3 shows a number of continuous diagrams from the engine after a slight addition had been made to it. In all these diagrams the compression pressure is very much lower than the minimum pressure hitherto believed to be necessary for self-ignition. In the fourth explosion the compression pressure is 350lbs. per square inch, and the maximum explosion pressure in this case is 620lbs. per square inch. In the 16th explosion the maximum pressure is 600lbs., and the compression pressure is 260lbs. In the second row of these diagrams, ignitions are shown to be taking place quite regularly with a compression pressure of 220lbs. per square inch.

Fig. 4 shows diagrams for the starting air and explosions due to self-ignition, with a compression pressure of 330lbs., and a maximum explosion pressure of 600lbs. per square inch above atmospheric pressure. These diagrams were the first taken on a certain morning when the engine was first started from "all cold."

Fig. 5 shows self-ignition with a compression pressure of 250lbs., and with a maximum pressure only a little in excess of this.

Fig. 6 shows self-ignition when the compression pressure was only 160lbs. per square inch above atmospheric pressure.

Fig. 7 shows a light spring diagram, and indicates one way by which it has been possible to obtain ignition temperatures without a high compression pressure.

The equation to the compression curve (Fig. 8) is $pV^n = C$, and from this it follows that

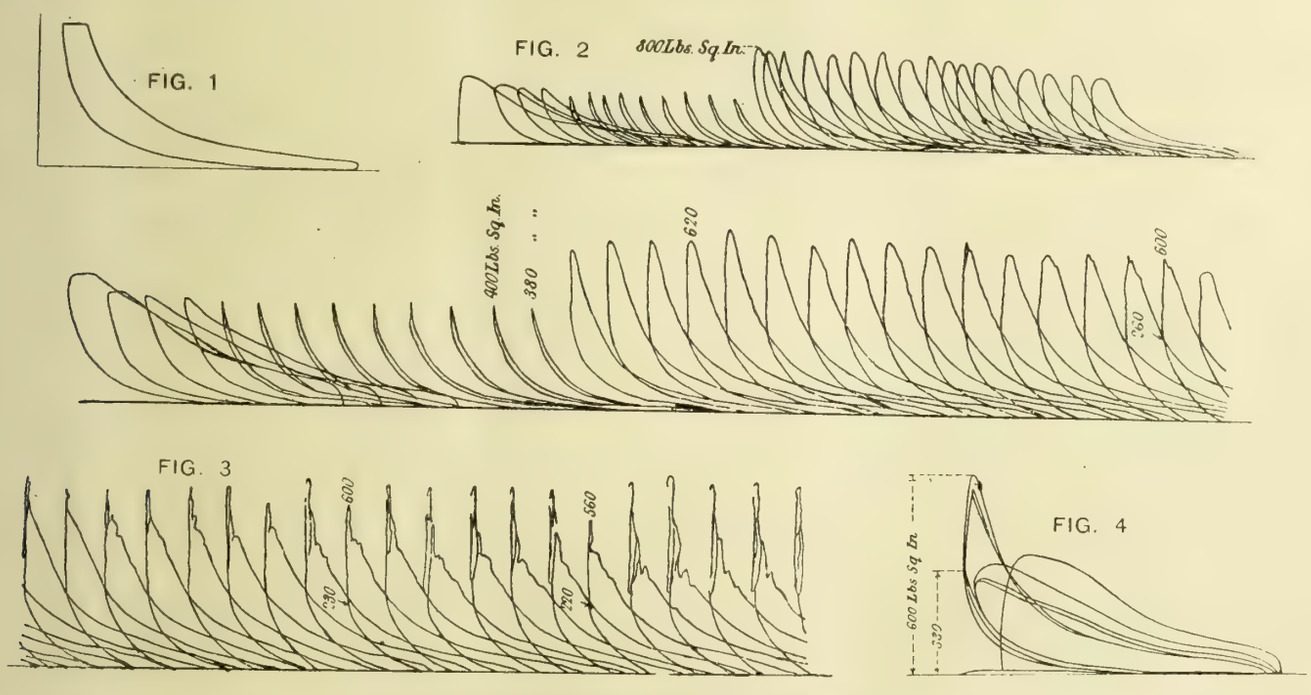
$$\frac{\tau_a}{\tau_b} = \left(\frac{p_a}{p_b}\right)^{\frac{n-1}{n}} = \left(\frac{V_b}{V_a}\right)^{n-1}.$$

These equations show that the temperature at the end of compression, in any given case, depends on the ratio of compression and not on the magnitude of the pressure at the end of the compression.

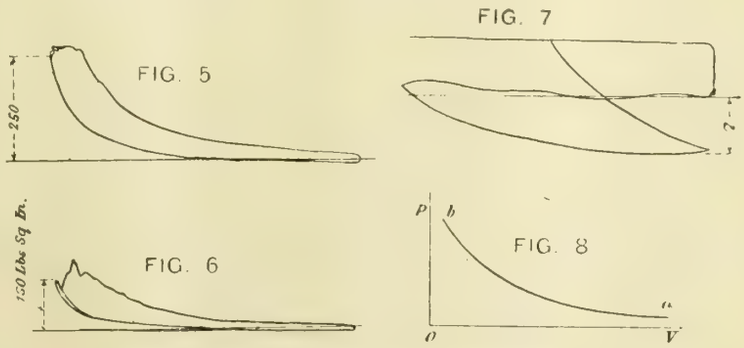
In accordance with the experiments of the late Dr. Joule, the temperature is not sensibly reduced by wiredrawing and, therefore, its temperature at the beginning of compression is independent of the pressure there, and the temperature of the air at the end of compression is independent of the compression pressure. It should be as easy to obtain ignition temperature by compression to two atmospheres as it is to obtain it in the ordinary way by compression to 34 atmospheres; but I have not yet made the experiment with such a low compression pressure.

I need only refer here to one application of the above method, although there are several that appear to be important.

To avoid the very high pressures obtained during the



STARTING DIESEL ENGINES WITH LOW COMPRESSION.



STARTING DIESEL ENGINES WITH LOW COMPRESSION.

* Paper read before Section G of the British Association, September 7th, 1916.

starting of such engines, it is only necessary to throw the mechanism operating the air admission valve out of action, and then the spring on the valve spindle will automatically control the wiredrawing of the air admitted to the cylinder, and the maximum explosion pressure during the starting of the engine will then be limited to about the normal compression pressure, instead of its being 800lbs. per square inch or more.

VOLTAIC CORROSION AND ITS PREVENTION.

BY THOMAS J. ROGERS.

NUMEROUS methods have been suggested and employed for the protection of those parts of a ship's fittings which come in contact with sea water, among which zinc has been extensively used for this purpose from its electro-positive character. The influence of this metal in protecting another which is negative to it and under the salt solution is a subject that has occupied the attention of practical men for a long time. It is one of very great importance at the present time, as corrosion takes place to an alarming extent on those fittings which have to conduct sea water to the various points in the modern steamship. To protect these fittings many experiments have been tried, and no appreciable results have been obtained.

From a careful observation of salt-water pipes, which have been repaired or renewed under the author's supervision, he is convinced that the excessive pitting is due to a gas, or a combination of gases, and that wherever a zinc plate or ring has been placed in the neighbourhood of these fittings to prevent galvanic action, the pipes are always severely pitted at the top part of the inner surface as they are placed in the ship, and that their length of service is very short in comparison to those which have not been placed under the influence of this metal, as in the manner herein described.

The method employed to prevent galvanic action to plating of hull adjacent to the openings of sea valves is to fit a cast zinc ring in the apertures of supply and discharge pipes below the water line This arrangement under the most favourable conditions is only a partial protection, which will induce a more negative state to the metals in proximity of the zinc, and render those parts further distant more positive. Such a diversity of conditions will give rise to voltaic action between the extremities, and from this inequality of protection it is productive of numerous evils which, when arising in one locality, may become contagious and affect the whole surface exposed to this influence. It can be readily imagined that the zinc ring has, from the manner in which it is secured, a metallic contact with the lip of the composition stool which pierces the hull. A pair of metals so arranged will not be able to generate much current, and the conditions are such that it is not applicable for the purposes for which it is intended, as the conducting powers of the composition and copper connections are so much superior to the salt water and the plating of the hull that whatever of current is excited will find the easiest passage through the fittings, and as there is no electric effort in the direction of the plating, it being a positive metal in this series, will be given a more positive value in the solution.

It is a well known fact to electro-chemists that when copper and zinc or composition, and copper and steel and zinc, as in this case, are placed in a salt solution they form a single fluid battery with two parts of metals, and no battery of this order will generate and maintain an electric current of a uniform constancy of strength to protect the metal from dissolution by galvanic action, as the surfaces of the positive metals soon become decomposed in their order, and the negative metals by becoming polarised from the gradual accumulation of hydrogen gas upon their surfaces, become insulated and give a counter effect in the solution.

In applying this principle as a means of protection there are other elements which have not been taken into consideration. There are possibilities of the electro-chemical action at these points setting free many elements contained in sea water which are injurious to a ship's fittings. In the action between the sea water and the metals hydrogen gas is evolved. This gas alone is harmless, but there are cases in which it enters into combination with other elements and dissolves those metals which have an affinity for it. Hydrogen, when in the act of being evolved by the agency of a metal, manifests sufficient activity to decompose other existing combinations present in the water and appropriate their elements, thus forming new compounds. It is well known to chemists that when a current of electricity is passed through a salt solution the salt contained in the solution will become decomposed, caustic soda being set free from one point, and chlorine from the other point of the terminals. Chlorine alone acts with great energy upon most substances, disintegrating them and forming new compounds. It has a chemical affinity for hydrogen gas, and under favourable conditions will combine and form one of the greatest solvents known.

From the location of the apertures in the hull of a vessel, and the specific gravity of these gases, they are compelled to arise and pass through the system of pipes when the valves are open, and when closed to escape to the surface water along the outer skin of the hull. From the great tenuity of these gases they have a great penetrative or rapid diffusive power; many metals are penetrated through their pores, and when there is adhesive attraction or a feeble chemical affinity between them and the metal they will condense on its surface or in its pores. Eventually these gases find their way into the boilers through the feed-pumps, which have sea connections through the salt water "make-up" at the condensers, or through the packing of tubes in condenser heads, which it is very difficult to keep perfectly tight, and which in some cases are even allowed to leak to make up the deficiency of feed-water. By this questionable method of engineering considerable of this gas finds its way into the condensers, the bubbles of gas in travelling along with the circulating water through the tubes becoming trapped in the ferrules, and with the assistance of the vacuum on the steam side and the pressure of the circulating water on the other, it is forced into the condenser, carried down with the condensed vapour, and dissolved into the feed-water. From the continual inflow of this gas the feed-water becomes highly charged with it, and those metals in the circuit for which these gases have a liking are readily disintegrated. Copper in its free state is a preventative of crustacean or other marine growth, but under existing circumstances, from the increased negativeness of the fittings in proximity of the zinc, they grow abundantly upon the inner surface of the fittings for a distance of 6ft. from the aperture, and to such an extent as to reduce the area considerably. Beyond this zone of marine growth, corrosion of the copper connection commences and continues throughout the system as far as the gases reach, and the greater the distance from the zinc the coarser is the pitting, demonstrating that one point is protected at the expense of another.

The author has seen some specimens of corroded copper tube selected promiscuously from a defective salt-water system, and cut open at the bottom of the pipe to show the extent of the corrosion from the gases which travelled along with the water. The bottom and sides of this system of pipes were free from pits, and showed a uniform wear from the friction of the water and the action of the salt, but were good for several years' service although the extent of the corrosion made it economical to renew the sections so affected. The length of service of these fittings was nine months, but with the thickness of metal used it should, under fair conditions, have given at least the same number of years' service. This corrosion is often attributed to imperfections in the metals, but allowing such to be the case, it is impossible for a mechanic in making and installing a system of pipes to get the imperfect parts of a tube or sheet from which the pipe may be made, always at the top.

If the practice of placing zinc rings in the openings before referred to, as a means of preventing galvanic action at these points, is continued it might be advisable to fit gas chambers on the top parts of connecting pipes at, or as near as possible to, the sea valve to trap the gases as they are evolved, and lead small pipes from the tops of the chambers to and through the hull above the water-line to release them. Similar pipes should also be led from the top of both ends of the condensers to release the gas trapped in the covers, which will thus also ensure a solid flow of circulating water and improve the efficiency of the condensers. The composition fittings which pierce the hull below the water-line might be coated with an enamel paint or porcelain that is impervious to sea water, so that when the sea valves are closed there will be no action between these fittings and the plating of the hull.—"International Marine Engineering."

ECONOMIC PROBLEMS OF THE ENGINEERING INDUSTRY.*

BY F. W. REED, M.I.M.E.

IN looking round for an appropriate subject on which to address you to-night, it appeared that we could not be more usefully employed than in reviewing some of the economic problems of the engineering industry as they stand revealed in the light thrown upon them by the state of war in which the old world is now involved, and which are urgently calling for adequate and fundamental solution, so that we may be prepared for the cessation of hostilities. For, scarcely will peace have been proclaimed than industrial war will be upon us. Even now our organisation should be ready.

We are well acquainted with the organisation and productive capacity of the great neutral power of the new world. Will it be less or more powerful in industrial competition with the great influx of gold to it from, in part, our unpreparedness? The complete industrial organisation of the chief central enemy power stands by the war revealed; will that organisation cease to exist with peace, or will it be intensified into greater perfection and activity? We shall be secure only in the latter belief. Already we have warnings that these countries are making strenuous preparations for capturing foreign trade after the war—let us be prepared.

In most of our establishments general work has been displaced by the making of machinery for the manufacture of munitions, whilst in others both the shops and machinery have had to be adapted to the making of shell and other war material. One of the problems which will come with peace will be the readjustment of these establishments to pre-war conditions. The Government and all concerned will do well to give the methods to be adopted their most earnest consideration. The men, as they become released from military duties and who so desire, must be reinstated in their former occupations. At the same time there will be a number who will not return to the trade; apart from casualties there will be some who will no longer desire to return to their former trade, and some others will remain in the army for the time being; and so we shall be depleted of a number of skilled workers.

That there will be a demand upon our industries with the cessation of war there can be little doubt. The making up of leeway in civil requirements, the work of reparation and renewals until devastation has been obliterated, will still tax our energies to an extent little, if any, less than we are experiencing in the call for war material. There can be little doubt of the labour capacity of this country for meeting that demand, providing it is organised on the best lines for economical production. For what do we see—our industries depleted of thousands of skilled workers serving their country in the field, and yet, under the stimulus of national determination, our works and factories continue to produce not only munitions of war, but manufactured material for export and home consumption. During the war we have become inured to rapidity and efficiency as the essential factors of our existence.

The sudden change over of our manufacturing resources to civil work will be a task of considerable magnitude. A great quantity of additional machinery and new works which have been forced into existence by the war will be available, and can, no doubt, be largely utilised for civil work. Owing to the high-pressure conditions and the little opportunity to make good wear and tear of the past two years, considerable repairs will be necessary, so that a very liberal allowance for depreciation is imperative, not only to put our machinery in order but to cover the cost of the unduly large number of machines which will have reached the stage beyond repair.

A large portion of this additional machinery had to be imported, our capacity not being able to meet the demand. The unprepared state in which the outbreak of hostilities found us should be an incentive to make a very large increase in our productive capacity; it is necessary for our national safety, and for the increase of our country's revenue. And it will be wise to assume that to maintain and increase our position in the neutral and allied markets we must supply goods at least as good and cheap as any of our competitors; for this object specialisation is essential. The Government would be well advised when adjusting war taxation to see that our industries are not impoverished, for without means no progress can be made.

Our dependence on foreign countries for some essentials to our industries has brought itself forcibly to our notice since the stoppage of supplies from Central Europe. In the manufacture, for instance, of dyes, optical and chemical glass, porcelain articles of trade, and magnetos, our foreign competitors had practically captured the world's trade. But with regard to the manufacture of magnetos, we have now established this industry with success, and, having overcome considerable difficulties, particularly in manufacturing the vulcanite insulators, we are now turning out magnetos in thousands. This is an excellent example of the efficacy of standardisation and quantity output, which principles we shall have to greatly extend in order to hold our own in the future. The importance of these principles is further particularly well illustrated in the motor-car trade. Our manufacturers should seriously consider their application by American competitors, where the maker has decided on a standard design, and manufactures in large quantities, two essentials to good quality and low costs. To attain this he employs the most modern automatic machinery, wherever possible, and is not handicapped by restriction of output or customers' fads, the manufacturer leading the buyer instead of the buyer leading the manufacturer, as too often happens in this country. Now, what is true about motor-cars is equally true about many articles of foreign make.

Why have we allowed ourselves to become so dependent? The position has long been revealed in our import trade returns—a source of useful and vital information we are very apt to overlook and neglect. There is no suggestion that we are wanting in scientific skill or manufacturing ability, but we want better organisation and more determination to overcome inertia, and to infuse more and more enthusiasm into all our industries, as no amount of legislation will help us without individual and collective effort.

The Government Department dealing with trade matters does not appear to meet modern industrial requirements; having widely divergent duties it is not able to give that assistance to industry which is desirable. The importance of this matter is such that it seems necessary that there should be established a Ministry of Industry and Commerce; such an organisation should, amongst other activities, collect from an improved Consular service, or from other responsible agents abroad, full information regarding trade possibilities, and issue reports promptly to the industries specially concerned.

Capital.—In the immediate future, more adverse conditions may be anticipated with regard to the capitalisation of industrial undertakings. But this question is one that is now receiving the attention of the Government and of financial experts. It is well to remember that German industry has been assisted by their Government, and it is even stated that those German industries which are not engaged on war work are being given financial help in order to manufacture goods to be ready for markets on the conclusion of hostilities. Further, German banks have given greater assistance and latitude to their clients than is usual here, and their State railways afford special transport facilities with a view of assisting their foreign trade.

Labour. Amongst the important problems that will arise after the war, there will be the questions of restriction of output and the dilution of labour, which even now are deserving of serious consideration. It is well known that for the purposes of the war, trade unions have agreed with the Government to withdraw their rules bearing upon these vital questions on the understanding that they will be reinstated on the return of peace conditions. As a set-off to these conditions, it is well known that the employers are called upon to make considerable sacrifices in the way of handing over to the Government any extra profits above a certain limit which may be earned through their extra endeavours and running their works, in many cases, continuously.

If labour insists that these rules shall be restored the Government will have to comply; this is the present agreement, which cannot be departed from without the consent of

* Presidential address delivered before the Manchester Association of Engineers, October 14th, 1916.

organised labour. Whether it will be to their ultimate interest to insist on this restoration is a very important matter for their consideration, and both employer and labour must realise that the conditions of industry will be changed, and both will have to meet the situation in a new spirit. Labour will do well to consider whether, after all, its own interests and the interests of the nation have been served well in the past, or will be in the future, by their late policy.

Why did the Government press for the suspension of these rules? Because it was well known that they were a means of restricting output, not only in ordinary times, but at a critical time when our forces demanded a maximum supply of munitions. It is obvious that a nation does not prosper by curtailing its output of things necessary for the welfare of mankind. For if our competitors produce the same things at less cost per head the trade will go to them. Our future success will depend on getting the utmost production out of our industrial equipment.

It may be argued that this position is taken up by labour in order to secure employment for a maximum number, and so, by getting all the labour of the particular class absorbed, strengthen their position; possibly some few advocates of the policy are prompted by mistaken socialistic ideas, and wish to fix a standard easily attainable by the most incompetent of their associates, and so secure equality of wages and equal security of employment. If such be the reasons, surely it is a bad economic policy. Another reason put forward is that if a worker increases his efforts employers would reduce piecework prices; this, whatever may have been in the past, cannot now be accepted since the practice exists when there is no piecework.

The sooner the workshop remark about "spoiling a good job" is a thing of the past the better it will be for all concerned. The idea of there only being a certain amount of work to do, and the less any individual does the more there will be for others, is economically bad, and to follow it up is to traverse the high road to unemployment; the reasons for this are obvious, and require no explanation. I do not suggest that any sweating system should be advocated, but a reasonable amount of work in a given time and no deliberate retardation of output. The skilled workman has been in receipt of high wages during the war, and will probably not be content to revert to pre-war conditions.

On the other hand, he still has it at the back of his mind that if he uses his best endeavours and thereby gets greater output, he is in fear of getting into disgrace with his union and some of his fellow-workers. I do submit that this pernicious practice of restriction is one of the most severe handicaps we have on our industries, and it is absolutely necessary that it should be cleared away, once and for all, if we are going to win the after-war of commerce and industry.

The great amount of capital outlay expended in equipping an engineering works forms an important proportion of the standing charges; therefore, the obvious policy is to obtain the maximum output per machine even to the extent of keeping the more important ones running night and day, and to encourage the workers' endeavours. A scheme of rewarding individual effort is advisable.

Recently we have heard much of the capture of enemy trade. This, again, is a question of output rather than of total employment, for in normal times we have only about 4 per cent. of unemployed, and if employment be found for these it cannot be expected that we shall be able to accomplish anything but a small fraction of the extra trade contemplated, unless an understanding is come to between employer and labour to ensure greater individual output, and it will be to the interest of the employer to discard out-of-date machinery and replace with modern; more especially is this advisable with high wage rates.

Dilution of Labour.—The unskilled male labour which has become semi-skilled should, I submit, be made the best possible use of in the national interest. Frequently in the past obstacles have been put in the way of unskilled men rising by ability and industry to semi-skilled or even skilled workers. This seems to be hard and unfair treatment of the individuals in question, and in the national interest advancement should be encouraged. It must be remembered in this connection that there are many operations in an engineering works that do not call for a long apprenticeship, and thereon such men could be most satisfactorily employed without detracting from, but rather improving, the status of regularly trained skilled men, who might be employed on more important work. The gradual change from making an article to manufacturing it on a large scale demands an alteration in the direction indicated. Surely it is not good economy to employ fully-skilled men on work which can be equally well done by semi-skilled men or women.

The war has taught us much, and it is to be hoped that the knowledge gained will be fully utilised in the future, and it behoves both employers and employés to consider the questions in a broad, conciliatory, and national spirit, and be ready to apply all their technical skill and practical wisdom to reach a satisfactory conclusion in order to further maintain our industrial prosperity. Further, we may assume that the future will bring very keen competition, which will necessitate, as far as possible, the extended use of modern tools and the most economical means of working them. There will no longer be room for antiquated methods and obsolete machinery.

The important part women have taken in helping to carry out extra and unusual work which the war has brought about is an important industrial factor. They have adapted themselves to the novel conditions, and have proved themselves capable of keeping pace with male labour on repetition work, even to the extent in some cases of giving better results. I particularly refer to output rather than to production costs. Not only have they shown themselves capable of success in engineering works, but they have taken the places of other male labour. Will these women be willing to revert to their former employment after qualifying themselves in doing work for which they have received comparatively high pay? No doubt there are a number who are working from purely patriotic motives, and who will resume their former occupations, but there are others who will have a strong desire to continue working in the mechanical trades.

The attraction of skilled women workers from other trades to munition work is an aspect of the position which should cause serious consideration, for on the return to normal times there will be a call for them to resume their former occupations. The number of women workers in July, 1914, in the United Kingdom was 5,020,000; in April, 1916, the number had risen to 5,490,000, an increase of 470,000; this is about five times the normal increase. No doubt this is due to the agreement of the trade unions to the dilution of labour, and to a patriotic desire to help in the production of war material. Only in rare cases are women doing the work of skilled men; in general, they are employed on work of a repetition nature, but the skill which they have displayed affords reason to believe that they could be qualified for more responsible work by a proper system of more prolonged training. Whether the retention of women and semi-skilled male workers in the mechanical trades will continue after the war to a modified extent will depend upon the attitude of the trade unions on the matter of dilution of labour.

Remuneration.—Labour should have adequate recompense for services rendered, but should not expect more. To arrive at this, full consideration must be given to prevailing economic and trade conditions, and we must recognise that the cost of production must come within the limits of competition, bearing in mind that lasting benefits are not obtained by merely an increase of wages, but by developing the world's resources and making them available to mankind. The value of services rendered should not be measured by the time made, but by the work done. Good wages is a forward policy; it attracts the best labour and retains it, and, generally speaking, ensures the most economical production.

Wage rates in the present abnormal conditions are high, and are not economically sound, since the nation's expenditure is greater than its income, and its resources are not being developed to give a corresponding increase in the purchasing power of the recipient of these increased wages. These present rates have been termed war rates, indicating they may rule until the cessation of hostilities, when a readjustment may have to take place. This, we sincerely trust, will not be a source of friction, particularly at a time

when there will be the greatest need for industrial peace, and when it would be national folly to resort to strikes or to any interference with national industrial activity. In dealing with the question of wages it is fundamental that confidence should exist between the employer and employed, based on commonsense, frankness, and a disposition to give and take.

Conditions of Employment.—With regard to the present conditions of employment in our engineering works, they are not wholly satisfactory. There is a lack of proper understanding of what may or may not be done in reference to works management; alterations may be made with good intent, which may cause the workers to feel aggrieved, and ultimately bring about discontent and trouble. These conditions will probably be more marked when we resume civil work, owing to the experience gained during this war period on quantity production.

The following are some of the questions which call for solution: (1) To consider and come to a general understanding in reference to apprentices in all the various branches of the engineering trades. I feel that we do not pay sufficient attention to the matter of encouragement and training of our apprentices, who are the individuals on whom we depend to carry on our industries in the future, and it is the duty of all to help them forward as much as possible, both in their general and technical education as well as in their workshop practice. (2) To consider the matter of making the best use of adult and other labour which has become trained in mechanical operations during the war, and the advisability of introducing such adult labour as in the opinion of the management might be trained to be useful operators in an engineering works, and to arrange for the grading and progression of these workers. (3) To make arrangements for rewarding individual effort. At present some works and foundries are allowed such systems whilst others are not.

Would it not be practicable to have a Central Engineering Board composed of representatives of employers and labour, whose business it would be to arrange rules and regulations to govern employment to suit modern conditions? This proposition is deserving and calls for prompt attention. I feel sure such an arrangement would be the means of preventing misunderstandings, and would tend to ensure continuity of work. Such a Board might also form a final Court of Appeal for the settlement of disputes relating to labour and wages. It should comprehend thoroughly competent industrial and labour leaders who are constantly in touch with the economic and trade conditions of the day. In the event of such a Board being formed, having the confidence of the employer and labour, many disputes might be settled without resorting to stoppage of work.

I would like it to be distinctly understood that my object in making the foregoing proposals is in no way to detract from or interfere with the present engineering organisations, which I know are doing good work, but rather to supplement them in dealing with the more general and wider issues of engineering labour questions. I am also aware that an Industrial Council was arranged by the Government in 1911, but I have not yet heard of its services being utilised. This Council consists of representatives of employers and labour in equal numbers, and its business is to deal with industrial disputes which adversely affected the general public. Such a Council, having to deal with various trades, could not adequately fulfil the above suggestion. The engineering industry is so extensive as to warrant the formation of a special Board to deal with its own affairs.

Education.—I do not intend taking up much of your time in this important subject, as it has already had the strenuous attention of your Council, and I believe they have made out very practical and satisfactory proposals. I believe our system of education would be improved if these existing conditions were modified. It may be argued that we got on and made good progress in the past without such facilities, as we even now have; this may be true, but our early pioneers accomplished their achievements by strict perseverance, frequently educating themselves at very great effort considering the opportunities existing. During the early stages of our industries when England was practically the workshop of the world, we secured a firm hold of the world's markets, but we are now faced with strenuous competitors who have developed their national education and made themselves fully acquainted with the general principles and details of the work they have in hand. It must also be remembered that our work is daily becoming more complicated, and calls for higher and higher technical ability.

It is true that many kinds of work can be done efficiently by uneducated men, and it may be said that higher education is only of direct use to those filling higher positions. This may be true as far as it goes, but that is only a little way; economically it is wrong, as education confers both direct and indirect benefits by developing mental activity and intelligence, and is a means of ever increasing the number of individuals suitable for advancement. In considering our present system of education, does it lend itself to our requirements in the very best way, does its various grades lead directly up to the next, and so form a proper linking up of each grade in a systematically-arranged manner, so as to compare favourably and excel our foreign competitors? This subject should receive national consideration, and there are now indications that our general system of education will have the attention of the Government in the near future, when, no doubt, many improvements will be made.

Education is not a private or local business, but is by its nature a national one; efficiency and economy can only be secured by systematic national organisation. Recently I have given some attention to this subject, and am convinced that the administration of our educational institutions from a central source would secure better use being made of our present facilities for higher education, would prevent overlapping and want of co-ordination, and would also result in more provision being made to meet the national need.

The continental systems of education are examples of good organisation, but modifications would have to be made in any of these schemes in order to meet our requirements, and it is important that technical and commercial experts should advise in all matters relating to higher and technical education in order to secure the preparation of suitable men for our industries. It is desirable that the minimum age for leaving school should be raised so as to give sufficient time for all to acquire a knowledge of natural science, from which the study of applied science and technology could be more efficiently taken up, and if encouraged by scholarships and bursaries, coupled with the co-operation of employers, we should be assured of the most suitable students being prepared to meet the needs of science and industry.

One of the most important requirements for our national welfare with which education is closely allied is research, and it is important that this should not only be carried on for its own sake, but in conjunction with our industries in order to overcome difficulties that arise and to secure progress. The chemical industry has fully realised the great advantage of research work, and the success achieved on the Continent in this direction is no doubt largely due to the attention given to scientific education and the recognition of its fundamental importance by the captains of industry. Research is as essential to engineering as to the chemical or any other industry in order to secure progress.

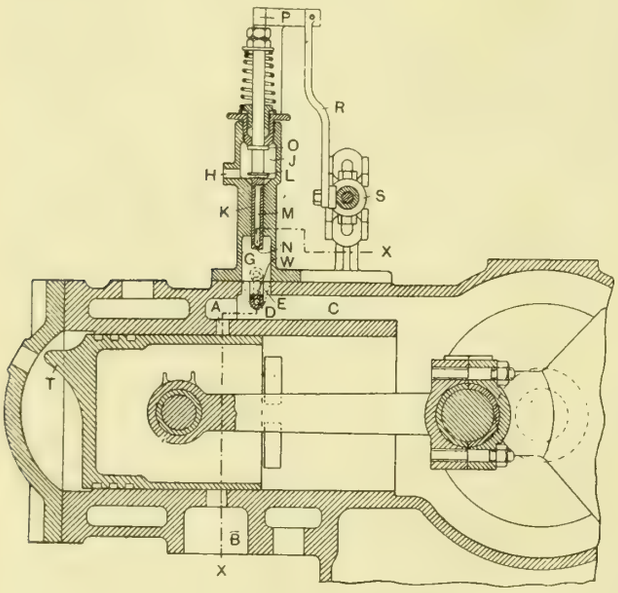
I believe at the present time there is no occasion to go out of this country to obtain the highest class of machinery, but to ensure future progress further improvements must be made. There is no finality, and research is the only channel by which we can accomplish this, and scientific education, coupled with experience, are the only means to help us in the process. In conclusion, I respectfully submit we shall come through this war a better disciplined people, and will certainly have learned in the past we had not reached the zenith of our productive capacity.

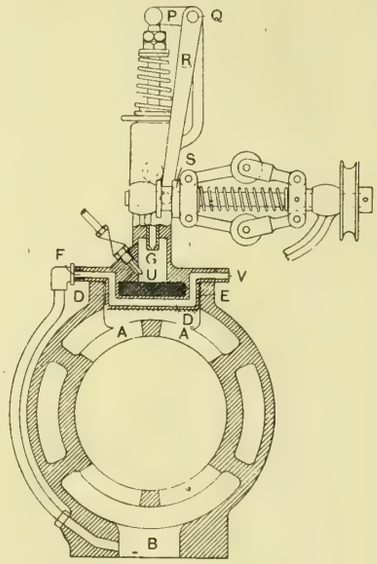
United States Pig-Iron Production. — According to the American Iron and Steel Institute, the United States produced during the first six months of this year 19,347,935 tons of coke pig iron, as compared with 17,473,500 tons in the second half of 1915. Including charcoal pig iron, anthracite, and mixed anthracite, and coke pig iron, the total production of pig iron for the first half of 1916 amounted to 19,610,522 tons. Of this total 8,830,085 tons was basic pig iron, 6,839,177 tons Bessemer low-phosphorus pig, and 3,086,410 tons foundry pig.

WALKER'S TWO-CYCLE OIL ENGINE.

We illustrate herewith a design of oil engine working on the two-stroke cycle, the joint invention of Mr. J. R. Walker and Mr. A. E. Walker, Oldbury Works, Tewkesbury, in which simple means are provided for heating and vaporising the petroleum and for mixing the hot vapour with the air to form the charge and also for automatically regulating and controlling the supply of the petroleum to the cylinder so as to maintain the engine at a constant speed under varying loads.

Referring to the illustrations, there is provided in the passage C leading from the crank case to the gaseous mixture inlet A to the cylinder an oil-heating member consisting of a hollow pipe D made to dip down through the opening E into the passage C, this pipe having at one end an inlet F connected by a pipe to the exhaust outlet B, the heating member having an outlet V opposite to its inlet so that some of the exhaust gases will flow into the heating member thereby heating the pipe D. The oil-feed attachment is bolted on to the top of the cylinder, and is formed with a hollow portion G immediately above the top of the pipe D, so that this cavity G and the opening E and back portion of the passage C together form an enclosed vaporising chamber, the oil being vaporised by being sprayed or dripped on to the top surface of the hot pipe D. Passing round the lower portion of this pipe is a piece of wire gauze so arranged that the vaporised oil will have to pass through the gauze which, being heated by being fixed to the pipe D, forms an increased heating surface for the vapour.





Walker's Two-cycle Oil Engine.

The oil inlet H is connected by a pipe to any suitable oil supply so that the oil flows or is forced into the chamber J, and in the lower part of this there is a vertical passage K leading to the lower chamber G, and in this vertical passage is fitted the circular stem of a valve L, which latter when closed down on to its seating closes the oil supply. The valve stem is made with a central passage M which at its top end has a lateral inlet and at its lower end is fitted with a drip or spray nozzle N through which the oil passes on to the top W of the heating member. The spindle of the valve L is continued upwardly through the gland shown, and against the bottom of this gland bears a collar O formed on the spindle. The spindle passes up through a stuffing box and is maintained raised by means of a coiled spring. Adapted to bear on the top of the valve spindle there is a short arm P of a bell crank lever which is mounted to rock on a fulcrum Q carried by a bracket. The longer arm R of this bell crank lever is at its lower end connected to the slide S of a governor driven from the engine crankshaft.

The spindle of the valve L is maintained in its raised position by the spring shown, the adjustment being such that the inlet into the passage M of the valve spindle is open to the right amount to pass the proper quantity of oil to maintain the engine at its normal speed with the required load. If this speed should be exceeded the governor draws the slide S towards the right hand in Fig. 2, thereby moving the bell crank lever and causing the end of the shorter arm P to bear upon the top of the valve spindle and to depress the same so as to partially close the inlet into the passage M and diminish, or by the valve L closing on to its seating to shut off the oil supply and thereby reduce the speed of the engine to the normal. Thus the supply of oil is automatically regulated to the load and the engine maintained at a constant speed.

Just before the piston arrives at the end of its forward stroke so as to open the inlet A and the exhaust passage B, the hot compressed air from the crank case passing along the passage C carries with it into the cylinder some of the hot oil vapour formed by the oil which by the suction of the piston on its back stroke has been sucked in from the nozzle N and dripped or sprayed therefrom on to the top W of the heating member D, thereby forming the proper gaseous mixture which passes through the inlet passage A into the cylinder and by the deflector T on the piston is deflected towards the back of the cylinder so as to drive out through the exhaust B as is usual the remainder of the products of combustion of the previous charge. The new charge is compressed in the cylinder on the back stroke of the piston and fired at the proper time at the commencement of the next forward stroke in the well-known manner. The engine is started with petrol or benzine until it is heated enough to vaporise the petroleum. The petrol is sprayed through a jet U into the chamber G and is regulated by a tap. On starting the engine the valve L is closed, which shuts off the petroleum supply and the engine is then worked with petrol until it has got sufficiently hot for the heating member D to volatilise the petroleum, when the petrol supply is shut off and the petroleum supply started by opening the supply valve L.

POPULAR SCIENCE LECTURES.*

At the meeting of the Council in June, 1916, representations were made by the Organising Committee of Section L (Educational Science) that much less attention is given to popular lecturing now than was formerly the case, and it was suggested that efforts should be made to promote increased public interest in science by means of such lectures. The Council, therefore, appointed a Committee representative of all the sections of the Association to institute enquiries into this subject and prepare a report upon it. Many local scientific societies, universities, university colleges, and similar institutions have organised popular science lectures, and the Committee has endeavoured to secure the results of the experience obtained, with the object of discovering the elements of success or failure. A schedule of 12 questions was drawn up and was widely distributed. To prevent misunderstanding, it was pointed out in an explanatory letter that the Committee was concerned only with single pioneer lectures for the general public, and not with students' courses, such as are arranged by University Extension authorities, the Workers' Educational Association, and other organisations.

In most cases local scientific societies arrange for the delivery of occasional popular lectures each session. These lectures however, are not usually intended for the general public, but for members of the societies and any friends who may accompany them. Lectures given in rooms of museums,

* British Association: Abstract of Report of the Committee, consisting of the president and general officers, Prof. H. E. Armstrong, Prof. W. A. Bone, Sir Edward Brabrook, Prof. S. J. Chapman, Prof. A. Dendy, Prof. R. A. Gregory (hon. secretary), Prof. W. D. Halliburton, Dr. H. S. Hele-Shaw, Prof. F. Keeble, Mr. G. W. Lamplugh, and Dr. E. J. Russell, appointed by the Council to consider and report on the popularisation of science through public lectures.

public libraries, universities, technical schools, and like institutions, attended by members of scientific societies and their friends, have usually audiences of about 30 in number, and the limit of accommodation does not often exceed about 200. From the point of view of local scientific societies, the most popular subjects are local archæology and antiquities, animal and bird life, and other aspects of natural history. The most popular public lectures are those on travel and adventure by explorers whose names are widely known. Astronomy is rarely mentioned, but this is probably because local scientific societies are mostly concerned with natural history, and there are few good lecturers on astronomy. Science lectures must be illustrated by lantern slides or experiments if they are to appeal to a large public, and their titles should arrest attention. The chief point, however, is that lectures should deal with recent discoveries or topics which have been mentioned frequently in the daily newspapers. The largest audiences are usually attracted, not by descriptive lectures on such subjects as mimicry, the descent of man, prehistoric animals, trade processes, and so on, but by those which are concerned with questions of wide economic or sociological interest, such as industrial research in America, wireless telegraphy in war, the wages problem, munitions of war, &c. One correspondent says, "Purely scientific lectures do not attract however eminent the lecturer. The most attractive lectures are the least scientific." For lectures to local societies, with audiences numbering from about 30 to 100, local lecturers "draw" as much as visiting lecturers of the same standing, but the visitor has to depend more upon the subject and title to attract an audience.

Few local societies have sufficient funds to pay lecturers. The result is that most scientific lectures arranged by these societies are given free or for out-of-pocket expenses. Members of the staffs of colleges and other institutions also usually give public lectures locally without fees. The general fee to professional lecturers, with lantern slides or experimental illustrations, or both, varies from three to ten guineas. As lectures to members of local scientific societies and their friends are usually given free, expenses are low and are met by the general funds of the societies. Very few localities have special funds available for the expenses of public lectures.

In answer to the question, Has public interest in popular science lectures increased or decreased in your district during the past ten or 20 years? about one-third of the correspondents reported that interest has increased, another third that it has decreased, and the remaining third that it has remained stationary or no decided change has been noticed. The whole matter is admirably summed up by Mr. D. B. Morris, town clerk, Stirling, as follows: "Comparing the position of matters now with that of 30 years ago, the popular lecture does not now occupy the place in public esteem which it did. For this there are various causes. With the better type of young persons, attendance at continuation classes, with their organised schemes of study, takes the place of attendance at popular lectures. To the non-studious the picture house is the habitual place of resort. Many of the films there shown are such as would be exhibited at a popular science lecture. As regards older people, some find that life has to be lived more strenuously nowadays, and rest or quiet recreation are sought in the evening rather than anything distinctly intellectual. The great popular interest which used to be taken in natural history, arising out of the 'evolution' controversy, and inspired also by the writings of Darwin, Wallace, Huxley, Lubbock, Kingsley, and others, has passed entirely away. Such interest now centres in subjects like wireless telegraphy, aviation, and, at present, all matters connected with the war. Serious students will always be found to attend courses where educational value is to be got, but popular lectures will not succeed unless illustrated by kinematograph, lantern, or experiments, or by all three. The element of entertainment must be present, which implies novelty. Arrangements might be made with local picture houses to have a fortnightly or monthly scientific evening, which would take the form of a popular lecture with illustrations. Tickets, containing a short syllabus of the series, could be sold at cheap prices, a local organisation assuming financial responsibility."

Many correspondents seem to think that popular lectures are necessarily of the instructive kind, and intended to induce people to take up courses of study at educational institutions. They have little faith in such a means of increasing the number of students, and rightly so. The purpose of public lectures may be, however, not so much to create desire to study, as to enlighten the community upon the relation of science to individual and national life. The point of view is thus entirely different from that of the local educational institution or the local scientific society, both of which regard popular lectures as possible means of securing new students or members. The position is clearly stated by Principal Garnett, School of Technology, Manchester, in the following reply: "A more general realisation by competent lecturers of the benefits which popular lectures may confer upon the community, and a greater readiness on the part of universities and colleges to spend money on the provision and advertisement of such lectures. The financial difficulty would disappear if an inspiring account of the broad outlines of natural science formed part of the curriculum of every elementary and secondary school. This 'science for all' is to be carefully distinguished from the science training given to those who are to pursue further the study of science in some institution of higher education or are to use it in their daily work." Mr. R. J. Moss, Royal Dublin Society, says: "Much more attention must be given to science in school education. It should be made interesting and taught as much as possible by demonstration and experiment. In this way the coming generation may be enabled to appreciate science and to take an interest in the progress of knowledge. A great deal of good might be done by the creation of travelling lectureships, to be held for a limited time by men who show an aptitude for the work."

It is obvious that a lecturer should adapt himself to his audience, and should possess expository power, so as to deal with his subject in a clear and interesting manner, without degenerating into the style of a public entertainer. Prof. Herdman states the chief element of success to be: "A good lecturer who can be heard, has a definite story to tell, and can tell it in plain language." This is also the view of Principal Garnett, who says: "The chief elements of success seem to me to be that the lecturer should be vividly conscious of the closest relation that exists, or that can be established, between his subject and the daily lives of his audience, and that he should possess an expert knowledge of his subject, a power of lucid exposition, and a pleasant and forcible delivery." Even in lectures to local scientific societies the subjects are frequently treated in too advanced a manner, and are, therefore, unintelligible to many of the audience. Experience shows that in an ordinary provincial town there is usually a small minority of intelligent persons who profit considerably from popular or semi-popular science lectures, but that the general community of the district is untouched by them. The provision now made for the study of scientific and technical subjects accounts, no doubt, for the failure of popular lectures in many districts. Mr. C. F. Procter (hon. secretary, Hull Scientific and Field Naturalists' Club) represents the views of many scientific societies as to the present position. He says: "Scientific lectures can only be made popular in the sense that you attract the crowd of unscientific people with a profusion of experiments, or, failing that, lantern illustrations. People will flock to the Egyptian Hall, and are vastly entertained and educated a little by an exhibition of what is often clever scientific acrobatics. Human nature loves to see what it cannot understand, and 20 years ago represents a period when the commonplaces of science were a wonderland to the average mind. The trend of education has altered that, and has sharply divided the same people into a minority of scientific enthusiasts who 'ask for more,' and a majority of indifferents who remain cold at a display of the old elementary stuff. Education—and that includes very largely the popular science lectures of the past—has created in this, as in all the arts, a small aristocracy of intellect, or, rather, comparatively small. These are not satisfied with anything that can possibly be popular. They are long past that, but will feverishly attend anything which proposes further to explore the deep water. The crowd—the man in the street and his women-kind—has had its wonder-bump excised in the school laboratory. Modern sensationalism in amusement and the plethora of scrappy, yet crisp literature—which religiously exploits every new thing, scientific or otherwise, that may entertain—has calloused this excision. The application of the film pictures to microscopy, &c., is about the only way to popularise science lectures, but—why bother? We cannot all be men of science, and the present system provides that any who get the call may answer it, whilst popular lectures only

attempt to entertain individuals of an age who are already past the slightest of hope of ever being useful scientists. The proper thing is already being done by our schools, universities, and University Extension lecturers with our budding professors." Many correspondents are of the opinion that the formation of a panel of lecturers, who would be prepared to assist small societies by lecturing for a small fee, would be of great assistance.

There is especial need at the present time of lectures showing the relation of science to many aspects of national life. Science and scientific method mean progress and efficiency, and the more this is recognised the greater will be the interest taken in the promotion of scientific study and investigation. The majority of the people in these islands regard science as a thing apart from their every-day lives, and even when they admire devotion to it or appreciate the advantages given them by scientific research, they think it is outside the world of practical affairs, whether commercial, industrial, or administrative. It is time that a systematic effort was made to remove this common impression and to bring science into close touch with social and political movements. By this means alone can a large body of opinion be created in support of the claims of science to an influential position in the State. The people as a whole will remain untouched by descriptive science lectures, however good the lecturer or important the subject, but they are ready to respond to a call for national efficiency associated with science in the place of the shibboleths of political parties of the past. What is particularly wanted to gain this end is lectures by advocates of science and scientific method, whether they are themselves professional men of science or not. The lecturers need not be original investigators or distinguished professors, provided that they are good speakers and have sufficient knowledge of the history of science and industry to show to an audience the debt which civilisation owes to its scientific workers, whether in the laboratory, the field, or the workshop. The time has come for the organisation of this propaganda work, and every encouragement should be given to societies or men who will take part in it. Political parties send lecturers all over the country to expound their principles. There should now be lecturers who will similarly spread the message of science and efficiency, and secure support for the men who will promote these factors in all departments of State. As titles of lectures having this intention, the following may be suggested: "England's Neglect of Science and Some of the Results"; "Unscientific Ministers and their Muddles"; "Politics and Trade"; "The Problem of Food"; "The Claims of Scientific Method"; "Lost Industries and How to Regain Them"; "Neglected Resources of the Empire"; "Politics and Education"; "State Control by Amateurs"; "Administration without Science"; "The Representation of Science and Efficiency in Parliament"; "Industrial Organisation and its Benefits"; "The Education of our Masters"; "Science in National Affairs"; "What a Ministry of Commerce might do for the Empire"; "The State as a Co-operative Society"; "Practical Education"; "National Waste and its Consequences"; "The Alliance of Science and Industry"; "Needs of Modern Life"; "How to Increase Work and Wages"; "A New Policy of Progress"; "The Promotion of Industrial Enterprise"; "National Economy in Fuel"; "Capital and Labour"; "Workshop Hustle and Fatigue"; "Healthy Homes"; "Nationalisation of the Highways"; "Railways as State Services."

Recommendations.—(1) That an annual list of public lecturers on science subjects be prepared and published, with titles of their lectures. (2) That committees organising public science lectures should include representatives of as many interests as possible. (3) That to extend interest in science, and belief in its influence, beyond the narrow circle of serious students, increased use of the bioscope in illustrating natural objects, scenes and phenomena is desirable. (4) That to carry on the propaganda of efficiency through science, local committees should endeavour to secure financial support from manufacturers and others affected by national progress. (5) That more encouragement should be given at university institutions and training colleges to the art of exposition and public speaking, for the benefit of those students and teachers whose aptitudes may later be usefully exercised in promoting interest in science. (6) That while the training of an adequate number of scientific workers is of prime importance, it is desirable that everyone should be made acquainted with the broad outlines of natural science while at school, and that public appreciation of scientific knowledge as an essential factor of modern progress should afterwards be created and fostered by means of popular lectures.

THE GRONWALL-DIXON ELECTRIC FURNACE.*

BY JOHN A. CROWLEY.

OVER a year ago the first Gronwall-Dixon electric melting and refining furnace was installed at Detroit. In conjunction with the basic Gronwall patents, there were combined certain American patents secured by Joseph L. Dixon. The Gronwall-Dixon furnace operates on a 2-phase system, energy being taken from 3-phase supply through two banks of transformers connected by a modified Scott 3-phase to 2-phase connection. In units of five tons and larger capacities, four vertical electrodes are introduced through the roof. The bottom electrode is embedded under the lining of the hearth, and is entirely protected from the molten charge. It therefore requires no water cooling. In capacities smaller than five tons, two electrodes are introduced through the roof.

Under the Gronwall-Dixon patents, the transformers are arranged to deliver a current at varying voltages, which are immediately available as required by the operator. Each phase of the 2-phase current, which takes a balanced load from the 3-phase supply mains, is carried to a pair of the vertical electrodes, the bottom electrode being joined to the neutral point of the transformers.

Through a special arrangement of switches the arcs can be thrown in series, or in parallel, or into several series-parallel positions. During the melting stage, while the arcs are in series, the lower electrode greatly accelerates the process by carrying a considerable proportion of current, as well as all the unbalanced loads, which in commercial operation are unavoidable. Because of this feature, the power input to the furnace may be greatly increased over and above the amount it would be possible to carry without the bottom electrode. In subsequent periods of refining, recarburising, and introducing alloys, or for holding the bath, the voltage can be reduced, shortening the arc, thereby lessening to a marked degree the reflected heat on the walls and roof. This procedure prevents rapid destruction of the refractories. When operating with a short arc the parallel or one of the modified connections are used, passing a large proportion of current through the bath to the bottom electrode. By this method the proportion of current flowing through the lower electrode can be varied within wide limits. From the power companies' point of view this transformer and connection arrangement makes a highly desirable load. The transformer efficiency is 98 per cent. or over, the power factor is 92 to 97 per cent., and the service mains and power station are not disturbed by any serious surges.

The Gronwall-Dixon furnace is cylindrical in shape and of the usual tilting type. The tilting operation is carried out through worm-driven connecting rods operated by motor drive through a reversing controller. The furnace is designed with two doors, front and back. The front door is a combination pouring and charging door, the spout being removable. The use of two in place of three doors, as is customary on electric furnaces, reduces the heat losses. The roof is built up in a supporting ring from regular and special shapes of silica brick. The entire roof is removable, and by providing a spare roof, very little time is lost in replacing, in case one is burned out.

The electrodes are carried by an overhead support made up of I-beams. Their weight is taken up by a counterbalance to which the mechanical gearing for the control is attached. This control is operated by an individual motor for each electrode, which is energised through a system of contactors located on a switchboard, either automatically or hand operated at a push-button station. Instruments for indicating the amount of current and voltage in each electrode are placed on a separate panel adjacent to the control and under immediate observation of the operator. The amount of current to be passed through each electrode can be set at a number of different steps by the operator. The current will be main-

* Paper read at the American Foundrymen's Association convention, September 11th to 15th, 1916.

tained at such point by the automatic control. All levers for operating the switches are brought to a panel so that the entire operation of from one to four furnaces may be carried out by one melter and his assistant.

The furnace installed at Detroit for the John A. Crowley Company is of five tons capacity. Up to August 1st over 800 heats of alloy steel for automobile and aeroplane construction had been poured. The results obtained have been so encouraging, from both a commercial and a metallurgical view point, that an additional 10-ton unit is now being installed, and arrangements for still further additions have been made. The operation of this furnace is continuous. The cold charge, consisting of various kinds and grades of scrap, together with a percentage of pig iron, is charged into the furnace, and from this material heats of high-grade nickel, chrome-nickel, chrome-vanadium, high silicon and high manganese, high carbon and high speed steels may be made within a period of four to five hours, with an energy consumption of from 500 to 600 kw.-hours per ton. Under favourable conditions many heats of steel refined to under 0·2 per cent. sulphur and phosphorus have been completed in a little over three hours with a minimum energy consumption of 460 kw.-hours

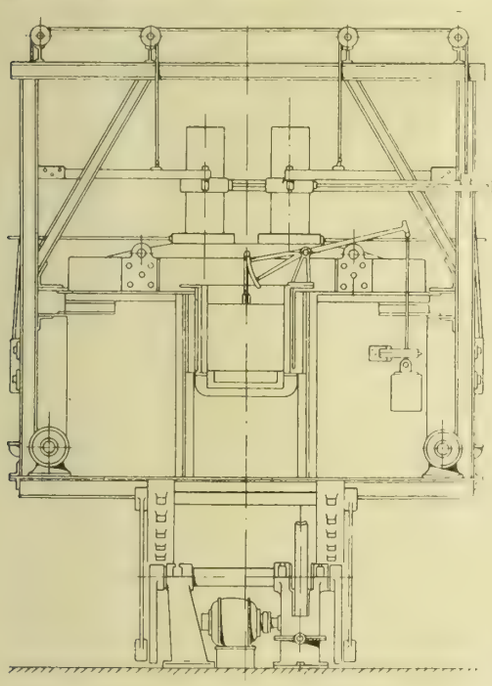


Fig. 1.

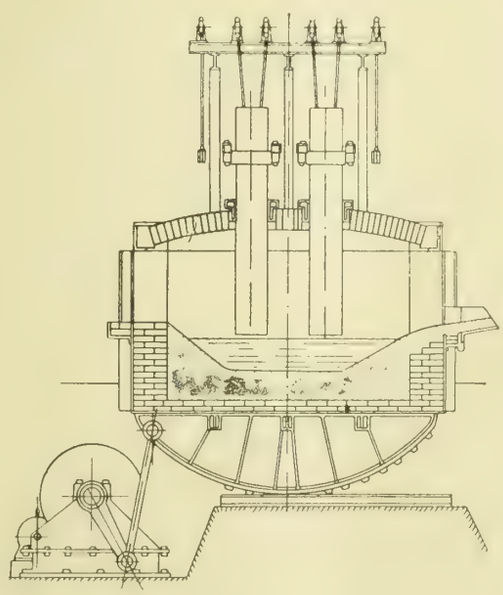


Fig. 2

Gronwall-Dixon Electric Furnace.

per ton. In making the above grades of steel practically 90 per cent. are to carbon specifications, requiring generally considerable recarburising of the bath as well as the addition of the necessary alloys. The specifications are in all cases exacting, and the charge must be held in the furnace while a sample is analysed for carbon by the combustion method, manganese, nickel, chromium, and vanadium, according to the grade of steel made. The above figures on power consumption include the time and energy consumed while the laboratory work is being completed.

In making the usual run of steels it has proved to be unnecessary to use any deoxidising agents, such as ferro-manganese or ferro-silicon, except as required to meet the specifications. Many heats have been poured where no additions of these elements are made. Owing to this neutral atmosphere, it is possible to add the greater part of the required alloys either with the scrap or immediately after the charge is melted, reserving only sufficient for a final adjustment of the analysis. Investigations of alloy steels made under this practice have shown an absolute uniformity and extreme accuracy in meeting specifications. After the melting operation, and during the refining, the passage of the current through the molten metal creates a magnetic movement of the bath producing three distinct results.

First.—It brings the entire bath in direct contact with the refining slag, materially assisting in removal of the sulphur and phosphorus. It is therefore possible, starting with a charge averaging as high as 0·10 per cent. in sulphur and phosphorus, to reduce these elements with one slag to under 0·03 per cent. Frequently the phosphorus and sulphur have been reduced to 0·01 per cent. with an additional slag. Extensive investigations of more than 800 heats have shown a minimum of segregation even in the piped section of bottom poured ingots. This rapid reduction of the sulphur and phosphorus is also brought about by the passage of the current through the bath, as it overcomes the tendency for the arcs to skim along the surface of the slag by drawing them directly into it. This method produces an exceptionally high temperature, particularly desirable when introducing the desulphurising slag, which must be made highly basic and steel kept sufficiently fluid to complete the removal of the sulphur. As there are no oxidising gases present, the sulphur is held in the slag.

Second.—This motion of the bath brings all of the charge under the direct influence of the arcs, and cold rings at the edge and chilled bottoms have never been experienced during the operation of the Gronwall-Dixon furnace in nearly 800 heats. It is therefore possible to pour all of the metal, leaving the furnace entirely clean for the succeeding heats.

Third.—The magnetic action of the bath produces a distribution and amalgamation of all the added alloys. This is particularly noticeable when making final additions for the adjustment of the analysis, such as metal for recarburising, ferro-manganese, nickel, chromium, or vanadium as may be required, after which additions the furnace can be tapped within 10 minutes.

That this passage of the current through the hearth is of decided benefit is shown by the fact that the initial lining installed when the furnace started nearly a year and a half ago, is still in good condition, and gives promise of lasting an indefinite period.

Another field for this furnace is the electric refining of cupola metal. Some of the results have been most encouraging. In one case fluid metal was taken from the cupola and refined in the electric furnace, the final analysis of the iron being as follows:

	Per Cent.
Silicon	1·980
Phosphorus	0·313
Sulphur	0·044
Manganese	0·730
Combined carbon	0·630
Total carbon	3·280

From the metal test a bar of 1in. square section was cast, the physical test being as follows: The bar was supported on knife edges 12in. apart and sustained a load, applied in the middle of 3,050lbs. before breaking, the deflection being 0·215in. The tensile strength was 27,570lbs. with a Brinell hardness of 202. So far the work has been carried on only in an experimental way.

The figures given as regards output and energy consumption are based on the making of high-grade alloy steels to meet severe specifications. In making the ordinary run of steel castings it is believed these figures can be greatly reduced, more especially as no time need be lost in sampling and analysing the metal during the actual operation. Generally speaking, a steel foundry requires a large number of small heats in quick succession. This is obtained by reducing the capacity of the furnace hearth itself, and increasing the transformer capacity so that the charges are melted quickly. Thus, by reducing the time cycle of operation, the production costs are materially decreased.

APPRENTICE SYSTEM FOR THE ELECTRICAL TRADE.*

BY A. P. TROTTER, B.A., M.INST.C.E., M.I.M.E., M.I.E.E.

OUR universities and technical colleges now make provision for the training of engineers, and the student must have had a suitable grounding in elementary science, and particularly in mathematics, before he enters the course. No engineer can join the Institution of Civil Engineers, or the Institution of Mechanical Engineers, or the Institution of Electrical Engineers, unless he has attained a certain standard of theoretical knowledge. We are not concerned here with those high and wide ranges of training for the profession about which so much has been written, but with a certain section of electrical trade. Some masters will not take boys from a secondary technical school because they come thinking that they already know a good deal, and most of this has to be unlearned. It seems therefore better, where possible, that the master should not only have some voice in the training, but should direct it, and this can best be done through the organisation of an apprenticeship system.

A boy is apprenticed to a trade. What is a trade? It originally meant a beaten path which we tread. Are these paths in the way of life wider or narrower than they were when apprenticeship was made compulsory for all trades? If at all times in the world's history a first-rate craftsman had a complete knowledge and practical experience of his craft, it follows that with the development of the arts the range that any one man can master is a fraction with a continually increasing denominator. There must be a continual splitting up of trades, and in Shakespeare's time there was already a distinction between a carpenter and a joiner. Division of labour was introduced for economy of production, and it is realised at the expense of narrowness of experience. I have met a maker of packing cases for pianos who was doubtful if he could undertake to make a case for a harmonium. In those trades where very highly manipulative skill is required, it is impossible for one man to do more than one job thoroughly well, and he should be content and indeed proud to be a specialist.

The old way of learning a trade was to give a lad simple jobs at first and let him gain experience in handicraft, and to acquire a general knowledge by keeping his eyes and ears open. The old craftsman seldom realised that any general principles underlay the methods he used. Much was traditional and much was rule-of-thumb. Sheer experience told him which methods would produce good work, and which would lead to inferior results. In the absence of any knowledge of general principles and of intelligent reasoning from them, it is no wonder that the word mystery was used in connection with the arts and crafts. With the development of science, which only means ordered or systematised knowledge, it was discovered that most of the methods of the craftsman could be explained in scientific terms.

Many modern businesses can hardly be called trades. How many people can make an electric glow lamp, can mix, melt, and blow the glass for the bulb, prepare the filament and mount it, exhaust and finish it? Then, again, in dynamo and motor building, what does a core stamper know about armature winding? It is difficult to find a name for these trades within trades. The essence of the contract of apprenticeship is that one person is bound to teach another a certain trade. What master would undertake to teach a lad how to make an electric lamp? One of the causes of the break up of the old apprentice system was the introduction of machinery, and with it, sub-division of labour in the textile industry; and this system is not readily applicable to some kinds of employment of the present day.

A change has taken place in the meaning of "a trade," but a greater alteration has occurred in the expression "master." We still speak in general terms of "employers and men," but we generally mean firms. Even where the firm consists of a father and son, or of two brothers, there is a blurring of individuality; where these, with a sleeping partner or two, constitute a limited or unlimited company, there is a further loss of the personal element, and in a modern business firm with a board of directors it is unusual, to say the least of it, to find a chairman, a managing director, or perhaps a secretary, of such a masterful character that any direct relationship with the apprentice can be recognised. It is true that the apprentice can work loyally for the "firm," in spite of the fact that it is a dim "they"; but who is to undertake the important duty of teaching?

In factory work, unless it is not only a recognised part of a foreman's job that he has to teach, and that he is able to teach and willing to teach, he cannot teach; and as we go down the scale we get further and further from the "master." In the case of house wiring, the firm, the vague "they," are remotely occupied in "the office," and are only represented by the flying visits of an inspector, while the charge hand is obviously the man who represents the master, but in such a different degree that only a trace of the old relationship with the apprentice can remain. On a large job, with several gangs, the apprentice is at a still greater disadvantage, and for the fulfilment of the obligation to teach or cause to be taught, some special arrangements must be made. It is a matter for employers to consider whether it is worth their while to take such steps, both during the ordinary working hours of apprentices, and by allowing them to attend trade classes, to secure young men trained to do good and intelligent work in the style of the firm, and well versed with its special lines. Apprenticeship will secure these. The inevitable wasters will drift in, but a probationary period of not less than one month but not more than six, will give them the opportunity of drifting out again.

Modern forms of indenture do not assume that the master will directly teach the apprentice, but he will "to the best of his knowledge and ability teach and instruct, or cause to be taught and instructed, the apprentice in the trade or business of——, and in all things incident or relating thereto. And that he, the master, will allow the apprentice such leave of absence as may be reasonable for the purpose of attending technical classes of instruction, and that the apprentice shall not suffer any diminution of wages on that account." In primitive times, the apprentice worked alongside his master and was taught by him, but as early as 1656, it was provided that "the said master shall and will teach instruct informe and bringe up or cause to be taught instructed informed and brought up him the said Apprentice. . . ."

Evening classes relating to the work on which a lad has been engaged all day are not desirable. They have their uses in certain cases. They require not only grit but a good physique. They are a valuable means of improving and widening the knowledge of those who have not had the benefit of a regular apprenticeship, or who have an ambition to rise higher in their trade, or to follow some other branches of their daily occupation. The apprentice should be bound to attend, and the employer should see that he does attend, the chosen trade or handicraft day classes (without loss of wages), for periods of at least two or three hours per week, or two mornings or afternoons every week, thus making a minimum of six hours weekly instruction in the theory and practice of his trade. For technical classes to be successful, it is desirable that the teaching should be in close touch with the trade, and employers should be invited to take an active interest in the scope and method of the training. This instruction should not be a mere extension of the daily work, carried on under the supervision of a teacher, but in the case of most trades it ought to consist of a study of general or scientific principles, illustrated or demonstrated by examples taken from the practice of the daily work.

In a science class a teacher avoids spoon-feeding, because he is using science for an educational purpose, and wishes his students to think out problems for themselves. He illustrates general principles and theories which constitute any particular science, by experiment. In a trade class much of this is reversed. The experiment, whether the tinning of a soldering-iron, or the charging of an accumulator, is the starting point, the main thing to be understood, and the principles and theories are brought in to explain it. In a science class the chemistry and transformations of energy in an accumulator are examples, much care is given to explain the distinction between electromotive force and difference of potential, and some years ago serious dissertations of a philosophical nature were given on the seat of electromotive force in a cell. In a trade class one of the first things to be learned about an accumulator is that the peroxide plate is positive and plum

* Abstract of presidential address delivered before the Association of Supervising Electricians, October, 1916.

coloured, and that the negative is neutral tint. That is not to be found, and probably never will be found, in a text book. Nor will you find there the fact that although mineral oil or vaseline are non-conductors they reduce the resistance of a sliding contact. If the teacher cannot explain this he can leave it as an interesting "mysterie."

The importance of systematic work should be taught. One man will fumble for an hour or more with a detector, sorting out circuits in a tangle of wires; another will finish them off in a few minutes because he works on a method. There may be a temptation to go rather deeply into the theory of locating a fault on a circuit, but here spoon-feeding is legitimate. Fully worked out examples should be given, and an hour spent on hydraulic analogies will enable some sort of mental picture to be formed of the circuit, although the whole thing could be set down in a few equations on the blackboard in ten minutes. Mathematics are absolutely essential for the higher branches of electrical engineering, and in the more simple departments, such as fault location, mathematics enable a trained man to take wonderfully short cuts. But a thorough grasp of the subject from a common-sense point of view will often enable a plain man to "get there."

But I cannot go into the details of the training which should be given. I am convinced that an apprentice should come so grounded in simple arithmetic that he should not have to be taught it, but only have to exercise his knowledge of it in the trade classes. I am neither a wireman nor a teacher. Nearly 30 years have passed since I managed a factory. It is for you, practical engineers, to decide what the apprentice should learn, and you should take care that it is properly taught.

In some cases boys are apprenticed while still at school, and the last part of their schooling is counted as part of their apprenticeship. To what extent school education should be specialised, with a trade in view, is a difficult question. It certainly should not attempt to deal with technical details or handicraft. On the other hand, if time can be found in a normal curriculum for putting every boy through a course of elementary carpentering, perhaps one-half of them may be educationally benefited thereby.

The demand for trade classes in any special subject must precede the supply. The City Guilds have done a great deal for higher scientific teaching. It would be appropriate that help should come from this quarter to revive apprenticeship, which was originally instituted as the carefully-guarded entrance to the Guilds, and that they should aid in the development of the guild spirit—a pride in craftmanship of the highest quality. Courses of instruction are already provided in London by the London County Council at day schools, to a greater extent than is generally known; and since these are by no means centralised but are widely distributed, they could be carried on in the same way, not only in other cities, but in the smaller towns. The L.C.C. offer about 150 scholarships tenable at these schools. Elementary and advanced evening classes for electrical wiremen are held at the Northampton Institute, St. John Street, Clerkenwell, and at the South-western Polytechnic, Manresa Road, Chelsea. Proposals for day classes would no doubt be considered.

The main advantage to the electrical engineering industry in encouraging the apprenticeship system, is that it secures good workmen thoroughly instructed in the craft. Apprenticeship, say, in the straw hat making trade has its own value, but in the case of electrical contractors engaged in wiring, sound workmanship becomes a matter of public importance. Ironmongers and decorators who have succeeded in putting up electric bells, have gone on to try their hands at wiring for electric light with disastrous results. I do not propose to follow that line of thought further, but I leave you to consider what ought to be done to check it.

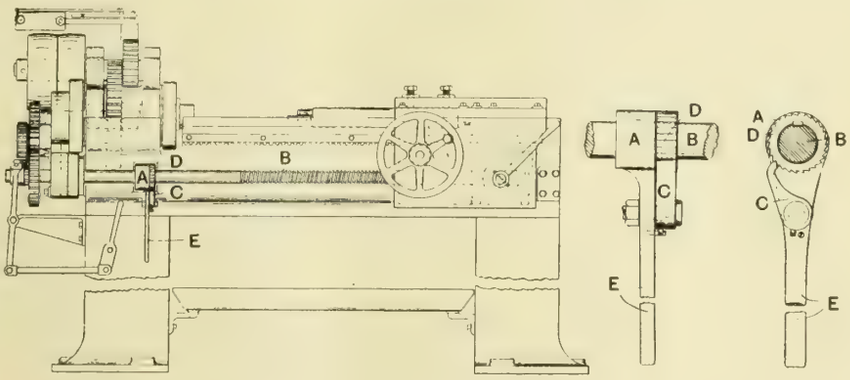
The old period of apprenticeship of seven years is too long in these days of competition and higher pressure. An apprentice who receives sound training in trade classes, and thus learns to understand his work intelligently, will master it sooner than a boy coming straight from an elementary school to pick up a trade by simply working at it. It is recommended that the period of modern apprenticeship should not exceed five years, and in some cases of simple repetition work, may be reduced to three. In general four years seems to be a suitable period for electrical contractors. If there is a variety of work, the apprentice may not have a chance of seeing it all during a period of less than four years.

When a consideration of a sum of money is paid to the master as a premium, the wages during a certain period are sometimes assumed to be the return of this premium. In general, the payment of a premium tends to put the apprentice in a false position. He is tempted to feel that his master is to that extent indebted to him, and this may affect his inclination to work. In the absence of a premium, relations become simplified, a small wage is paid, and this places the master in his proper position. Like most considerations of money, the payment of a premium depends on the principle that the price of a thing is what it will fetch. When apprenticeship was compulsory by law, a parent would often have to induce a master to take his son.

When I left Cambridge in 1879, I wished to become a mechanical engineer, and I paid to a fine old firm, which no longer exists, a considerable sum as premium for the privilege of entering their works as a pupil for three years. One of the partners gave more attention than the others to the dozen of us who were there. There was no indenture, and no obligation to teach or to learn. Opportunities for learning were abundant, actual teaching was insignificant. Most of us picked up a pretty fair knowledge of the trade, but nothing of the business of mechanical engineering. The premium pupil system has been severely criticised, and in rare cases it has been pushed to a scandalous extent, where small factories have been run with little else than the labour of premium-paying pupils.

HAND-OPERATED FEED DEVICE FOR BORING MACHINES.

MESSRS. ROSE, DOWNS, & THOMPSON, LTD., Old Foundry, Cannon Street, Kingston-upon-Hull, and Mr. W. B. Littlejohn have recently patented the device illustrated for enabling the lead-screw of boring and similar machines, in addition to being operated or rotated automatically by mechanical means, as heretofore, to be operated or rotated by hand when desired, whereby a reduced speed of feed of the cutter or tool can be obtained when necessary. Referring to the illustrations, A indicates a sleeve forming part of a ratchet device for rotating the lead-screw B, and which is mounted on that portion of the lead-screw which is not provided with a screw thread, the pawl or the equivalent C of the ratchet device being adapted to engage teeth formed around the lead-screw spindle, or around a collar D fitted thereon, E being the operating handle of the device, which is formed integral with or secured to the sleeve A, to which handle the pawl C is loosely pinned.



HAND-OPERATED FEED DEVICE FOR BORING MACHINES.

Manchester Association of Engineers.—At the opening meeting of the session, held on Saturday last, prior to the delivery of the inaugural address, the president (Mr. F. W. Reed) presented the "Constantine" gold medal for the past session to Mr. Alfred Etchells for his paper on "Uniform Conditions for Engineering Operations and Industrial Work."

TESTS OF LUBRICATING OILS.

In an article on the above subject which appeared in the August issue of the "Journal of the American Society of Naval Engineers," J. L. Kauffman states that up to about five years ago the U.S. Navy Department issued specifications for lubricating oil calling for a certain flash point, specific gravity and viscosity, and usually enumerated several simple tests that would be made. After the establishment of the Engineering Experiment Station, however, study and examination developed a number of special tests, which finally led to a change in the method of purchasing lubricating oils. Instead of requiring oils to meet definite specifications, each was required to pass satisfactorily tests made at the station before being placed on the acceptable list. A memorandum was issued to all firms bidding on navy contracts, setting forth in a general way the tests that would be made. The old method had the disadvantage that an oil could be submitted which would meet each item of the specifications and still would not lubricate properly. Also the requirements of the old specifications regarding specific gravity and flash point were found to limit the bids without increasing the lubricating value. The important paragraphs of the memorandum are:—

(*a*) All oils not known to be satisfactory are subject to test at the Engineering Experiment Station, and to a further test in service on board ship when considered necessary before being considered acceptable.

(*b*) The complete test of an oil consists of three parts, namely, chemical, physical, and practical tests.

(*c*) To successfully pass the chemical tests all oils should be neutral in reaction and should not show the presence of moisture, matter insoluble in petroleum ether (hard asphalte), matter insoluble in ether alcohol (soft asphalte), free sulphur, charring or wax-like constituents, naphthenic acids, sulphonated oils, soap, resin or tarry constituents, the presence of which indicates adulteration or lack of proper refining. Except in oil for engines without forced lubrication no traces of fixed oils (animal or vegetable fats) should be found.

(*d*) In lubricating oil for main engines without forced lubrication, approved fixed oils, such as rapeseed, olive, tallow, lard, and neatsfoot oil may be used. When the foregoing fixed oils are used, they must be well refined with alkalies, unadulterated, containing a minimum of free fatty acids, with no moisture or gumming constituents. Olive oil should not have a high specific gravity. If satisfactory emulsifying results can be obtained with straight mineral oils on engines without forced lubrication they may be submitted for service test.

(*e*) The physical tests applied to each oil are as follows:—

1. { Specific gravity—pyknometer.
   { Baumé gravity.

2. Flash and Fire Point (Cleveland open cup, Pensky Martin closed cup)—The flash point should not be below 300° Fah., closed cup; and for steam cylinder oil not below 450° Fah.

3. Cold Point—The cold point should not be above 32° Fah., except for cylinder oils. For ice machine oils it should be as low as possible, at least low enough for the operating condition of minus 15° Fah. in a dense-air ice machine.

4. Viscosity—The Saybolt Universal Standard Viscosimeter is used. The viscosity of the oils must be sufficient for the purpose intended, and except for ice-machine oils, must not be less than 140 secs. at 100° Fah. Viscosity is taken at 100°, 130°, and 210° Fah.

5. Emulsion Tests—Emulsion tests are made on all straight mineral oils except cylinder oils. Four emulsion runs are made, using 40 c.c. of oil in each case and (a) 40 c.c. of distilled water; (b) 40 c.c. of salt water; (c) 40 c.c. of normal caustic soda solution; (d) 40 c.c. of boiling distilled water. The mixture is stirred with a paddle for five minutes at 1,500 revs. per minute, the mixture being kept at a temperature of 130° Fah. during the stirring and while settling out. On oils used with forced lubrication or on ice machines the oil must completely settle out in less than 20 minutes.

6. Friction tests are made on the Experiment Station friction machine to determine the relative friction of various oils under varying conditions of speed, bearing-cap pressure and temperature.

(*f*) Practical tests of oils for forced lubrication are made on the Engineering Experiment Station's 75 kw. turbo-generator, making 2,400 revs. per minute, with the temperature of the bearing varying from 180° to 210° Fah. Tests of ice-machine oils are made on the ½-ton Allen dense-air ice machine. These tests cover a working period of at least 100 hours.

(*g*) Upon completion of the tests at the Engineering Experiment Station, a service test is usually recommended on all but cylinder oils. These tests are made on ships in commission and cover a period of several months.

(*h*) 1. Samples of three oils (light, medium, and heavy) should be submitted to be suitable for turbines, all forms of forced feed or splash lubrication, dynamo engines, and all internal-combustion engines (including Diesel type). These three oils should cover the required range of viscosity.

2. Oil suitable for main engines without forced lubrication should form an emulsion when mixed with water, may be either compounded or a straight mineral oil and must feed efficiently with wick feed, and not be washed off when mixed with water.

3. An oil for use on ice machines in both the compressor and expander cylinders should not give off an objectionable odour when used with the dense-air ice machine.

4. Oil for steam cylinder lubrication must be a straight mineral oil.

5. Oil for cylinders using superheated steam used on shore stations should have a high flash point.

The following is a description of the tests enumerated above:—

Moisture—Heat 3 to 4 c.c. in a test tube (the walls of which have been thoroughly wet with oil) in a bath of liquid paraffin up to 300° Fah. Oils containing water will form emulsions on the walls and cause foaming and spluttering. A test is also made with a mixture of oil and eosin to determine faint traces of moisture by changes of colour. The presence of moisture is particularly undesirable in transformer oils, but there is danger of its forming objectionable emulsions in any straight mineral oil

Sulphur—Boil about 50 c.c. of oil with a piece of bright metallic sodium for half an hour; add water, heat and stir until the sodium is dissolved; pour off the water and test the remainder with a fresh 1 per cent. solution of sodium nitro prusside. If the mixture turns violet colour, the oil contains sulphur. When sulphur is found, an additional test for sulphonated oils is made.

Acids or Alkalies—Heat for one half hour with frequent stirring 25 c.c. of oil and 50 c.c. of neutral distilled water. Test a few cubic centimetres of the mixture first with methyl-orange to determine the acids, and another portion with phenol-phthalein for the determination of alkalies. Acids and alkalies cause emulsions. Acids also cause corrosion of journals and other metal parts.

Matter Insoluble in Ether Alcohol—Shake 11 c.c. of oil and 14 c.c. of ether alcohol (8 parts ether and 6 parts alcohol). After standing 12 hours, note the precipitate, if any, at the bottom of cylinder. The precipitate will be asphalte, and even a trace would make the oil undesirable as a lubricant. Asphalte would cause scoring of journals and clogging of oil lines.

Matter Insoluble in High-grade Gasoline—Shake 2 c.c. of oil and about 300 c.c. of high-grade gasoline (86-88 Baumé gravity). After standing 12 hours, note precipitate, if any, in the bottom of glass. The precipitate will be soft asphalte or carbon particles, and a slight trace would make the oil undesirable.

Tarry or Suspended Matter—Same as the foregoing, except using 5 c.c. of oil and 95 c.c. of gasoline and allowing it to stand for half an hour; then examine deposit, if any, for dirt or tarry matter.

To Detect Fixed Oils—Heat 10 c.c. of oil with a small piece of metallic sodium. If the mixture becomes gelatinised or a semi-solid, it indicates the presence of fixed oils. If an equal volume of oil is heated alone to the same temperature, the viscosity of the two samples can be compared; if the oil contains fixed oils (animal or vegetable oils), the sample with sodium will be much heavier than the sample heated alone.

Effect of Heat—Heat 5 c.c. of oil in test tube over flame until vapours are evolved and compare the colour of the heated oil with that of unheated oils. If the heated oil turns

black, it shows the presence of undesirable carbon or hydrocarbons.

The physical characteristics are determined as follows:

Colour—The colour, although having no influence on the lubricating value, may be used to identify the sample. American oils fluoresce with a grass-green colour. Russian oils have a blue sheen; oils containing distillation residues and unfiltered oils are brown to green-black in reflected light. Nearly all mineral machinery oils are distilled and filtered to some extent and are transparent in a test tube, the colours ranging from a yellowish white to a blood red. The colour may be determined in a tinctometer by comparing with different coloured glasses or lenses. These glasses are numbered and for machinery oil extend from No. 1 (white) to No. 6 (red).

Odour—The odour may be determined by heating in a test tube or by rubbing on the hand, by which means fatty oils, coal tar, resin oils, &c., may be detected.

Specific Gravity—The specific gravity is obtained by the use of the "pyknometer," this term signifying any vessel in which an accurately measured volume of liquid can be weighed. The bottle is first filled with distilled water at a temperature of 60° Fah. and the weight of the water determined. The bottle is then filled with oil at a temperature of 60° Fah. and the weight of the oil determined. The weight of the oil divided by the weight of the water gives the specific gravity at 60° Fah. The Baumé gravity is obtained by using the Baumé hydrometer, which is simply an ordinary hydrometer with a certain arbitrary scale. Baumé gravity may be converted into specific gravity by the following formula:—

$$\text{Sp. gr.} = \frac{140}{130 + \text{Baumé}}$$

Baumé gravity is largely used in commercial practice.

The specific gravity does not affect the lubricating value of an oil, but indicates to the experienced oil man the locality from which the crude oil is obtained. For instance, the specific gravities of the lubricating oils tested at the Experiment Station vary from 0·864 to 0·945. A Baumé gravity of 32 corresponds to a specific gravity of 0·864, and a Baumé gravity of 18·1 to a specific gravity of 0·945, so that an increase in specific gravity is a decrease in Baumé gravity. The paraffin-base oils of Pennsylvania derivation have an average specific gravity of 0·875 with a corresponding Baumé gravity of 30. The asphaltic base oils from Texas and California have an average specific gravity of 0·930 with a corresponding Baumé gravity of 20.

Flash Point—The flash point is determined with both the Cleveland open cup and the Pensky-Martin closed cup. The flash point of all oils is determined as a measure of their volatility. The flash point of steam cylinder oils is of primary importance, the required flash point depending on the temperature of the steam at the engine. With lubricating oils for bearings the flash point is important only in that it indicates the volatility of the oils and the presence of kerosene or naphtha fractions, with the accompanying fire risks. In the case of very low flash-point lubricating oils, it is desirable to run a special distillation or volatility test, mentioned under chemical tests. The flash point determined with the open cup is higher than with the closed cup, as the inflammable gases on the surface of the oil are disturbed by the air currents in the open cup. These differences range from 5° to 40°, with the average of 20°. The presence of very light ends (kerosene, naphtha, &c.) may increase this difference to 100°.

Fire Point—This is the temperature at which the oil burns and is determined by raising the temperature about 3° a minute, applying the flame for about a second. The fire, or burning, point is from 30° to 65° higher than the flash point with all lubricating oils, the light oils having a difference of about 40°.

Cold Point—Mineral oils become more viscous on cooling, and finally solidify. In lubricating oils refined from paraffin-base crudes, cooling first causes the paraffin particles to solidify, which gives the oil a cloudy appearance; with this class of oils this change is known as the cloud point.

The Committee on Lubricants of the American Society for Testing Materials uses the words "cold test" as a general term, with sub-heads of "cloud test" and "pour test." The method recommended by this committee is used at the Experiment Station, and in substance is as follows: Heat the oil to 150° Fah. and cool by air to 70° Fah. Take a bottle about 1¼in. inside diameter and 4in. to 5in. high and pour in oil to a height of 1½in. from the bottom. Insert a cold test thermometer (specially made, using coloured alcohol, and with a long bulb) through a tight fitting cork. A special jacket is used having an inside diameter about ¼in. larger than the bottle. Ice or any other cooling medium is packed around this jacket. When the oil is near the expected cloud point, at every 2° drop in temperature remove the bottle and inspect the oil, being careful not to disturb the oil. When the lower half becomes opaque, read the thermometer; this reading is taken as the cloud point. The cold, or pour, test is simply a continuation of the cloud test, except that the temperature is noted every 5° and the bottle tilted till the oil flows. When the oil becomes solid and will not flow, the previous 5° point is taken as the cold point of the oil. In the naval service a low cold point is required only on ice machines. All ice-machine oils should have a cold point of minus 15° Fah., which will permit a brine temperature of minus 20° Fah. Oils used on motor-boat engines should have zero cold test if the boats are used in cold climates. The lubricating oils refined from asphalte-base crudes, or Southern crudes, have a natural cold point around zero degrees; these oils do not show cloudiness before solidifying. The oils from paraffin-base crudes, or Northern crudes, must be run through the filter presses to squeeze out the paraffin before a low cold test can be obtained.

Viscosity—The viscosity of a lubricating oil is the most important constant to be determined. The viscosity of an oil is inversely proportional to its fluidity and is a measure of its internal resistance, or resistance to flow. The absolute viscosity is determined from the amounts flowing through capillary tubes, the results being given in C.G.S. units. The determination of the absolute viscosity is a very difficult operation requiring complex apparatus and a relatively long time. Several absolute viscosimeters have been invented; but to date none of them are considered practical enough for the routine testing of oil. The accepted theory advanced by Ubhelohde is that the viscosity (absolute) is directly proportional to the internal friction of the lubricant, and that the viscosity is a direct indication of the friction developed in a bearing.

Under normal conditions of bearing lubrication, the lightest oil that will prevent seizing should be used to obtain a minimum frictional loss. Friction tests as shown by the station's friction machine are comparative only, the results being simply the friction obtained by using various oils on this particular bearing. Tests have been made that show that the friction is directly proportional to the viscosity of the oil at the temperature of the bearing.

Emulsion Tests—The method of conducting the test is described in the memorandum quoted at the beginning of this article. The emulsion is made with distilled and salt water, and a normal caustic-soda solution is also taken, as there is a possibility of water containing boiler compound getting into the system. Boiling distilled water is used in case gland steam or water runs into the oil system. These emulsion tests are considered of the greatest importance, as an oil on any type of forced lubrication system must not emulsify. If emulsions do occur, it will mean clogging of the oil lines, forming of residues in the base of the bearings, with a resultant loss of a large amount of oil.

Practical Tests—All oils submitted for forced lubrication purposes are given a working test on the Experiment Station 75 kw. turbo-generator for 100 hours, with the generator running at 2,400 revs. per minute. The oil is placed in the main bearing, which has ring-feed lubrication, and a careful record is made of the temperatures and of the amount of oil required to keep the reservoir full. After the test the bearing and journal are examined and the oil is analysed and tested. From the examination after use in the turbine, the action of an oil in service can be predicted as far as its lubricating value is concerned. Service tests are made on board ship, and it is a comparatively easy matter to obtain satisfactory oils by the employment of the tests enumerated and from the large amount of data accumulated at the Experiment Station. Whether an oil will prove satisfactory can be closely predicted by a consideration of the results obtained on the preliminary tests.

Special Tests—Due to the relatively small amount of

information obtainable on the action of lubricants in service, it is necessary to continually develop new tests in order that the new types of machinery may be properly lubricated. At present the study of oils after several hundred hours' use in service is being made. Particular attention is being paid to the loss of oil by vaporisation or volatilisation, and the resulting characteristics of the remaining oil in the system.

ELECTRIC POWER AND COAL ECONOMY.

In his presidential address delivered before the Birmingham Association of Mechanical Engineers, Mr. R. A. Chattock, the city electrical engineer, in referring to the waste of coal that takes place in this country, suggested that the transformation of the energy in coal into electrical energy should be made compulsory in the case of all users of coal for power purposes. He remarked that the Committee of the British Association appointed to report upon the subject, so far as their deliberations had gone, led one to believe that the greatest economy in the use of coal could be obtained by gasifying it and recovering its valuable by-products. It was impossible for individual manufacturers to do that with anything like the economy that could be obtained if the whole of the coal used in the country were so treated at certain convenient centres. The transformation of the energy in the coal into electrical energy was the one link that rendered a scheme of that kind possible, because if all the coal consumed in the country was so treated at certain centres the energy produced would have to be transmitted all over the country for use wherever it was required, and the only way of doing that with a reasonable capital expenditure was electrically. Electrical energy could now be efficiently applied to all purposes for which coal was used, and if energy could be produced and transmitted at a figure that compared favourably with what it at present cost the consumer to supply himself, the justification for such a scheme was made out. The production of electrical energy from such a scheme at a cost far below that which obtained at the present time would make it possible for all users of coal economically to use electrical energy in substitution for coal. It was doubtful, however, owing to the conservative nature of the average man, whether such a change could be brought about quickly enough to justify the erection of the large super-stations that would be necessary, and to make them pay for themselves within a reasonable time, unless special steps were taken for the purpose. Compulsion might be exercised directly by Government control of the coal supply of the country, or indirectly by putting a tax upon all users of coal who consumed it in an uneconomical manner, the tax being utilised for financing a scheme of the kind indicated until it became self-supporting. Compulsion would, in the author's opinion, be justified, having regard to the national importance of the results that would be obtained by the proper conservation of the coal supply of the country, by the elimination of smoke from the atmosphere, by the possibility of giving a supply of power to manufacturers and other users at a figure so low that it would represent a saving in their cost of production, and by relieving the congestion on the railways owing to the reduced traffic in coal, which at present had to be delivered all over the country, and under the suggested scheme would only have to be delivered by special lines to certain centres.

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Fire-bridges for boiler furnaces. Tye, J. P. 1460.
Lubrication of internal-combustion engines. Baylis, A. S. 2158.
Couplings for transmitting rotary motion at a variable angle. Hasler Akt.-Ges. vorm. Telegraphen Werkstatte von G. Hasler. 3606.
Explosion engines coupled to dynamos. Soc. Anon. des Etablissements L. Bleriot. 3817.
Apparatus for spraying liquid fuel and mixing it with air in internal combustion engines. Schmid, A. 4349.
Pumping installations. Lagorara. 5548.
One way friction clutch. Royce, F. H., Day, B. I., and Rolls-Royce. 7705.
Lubrication of pressure fed bearings. Svenska Turbinfabriks Aktiebolaget Ljungstrom. 11929.

ELECTRICAL, 1915.

Insulators for electrical resistances and conductors. Woodhouse. 12193.
Telephone systems. Datzevitch. 12404.
Electric selective devices. Morse, and Indo-European Telegraph Company. 13614.
Regulation of dynamos. Thury. 13801.
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Means for controlling and regulating electric motors. Igramic Electric Company. 8754.
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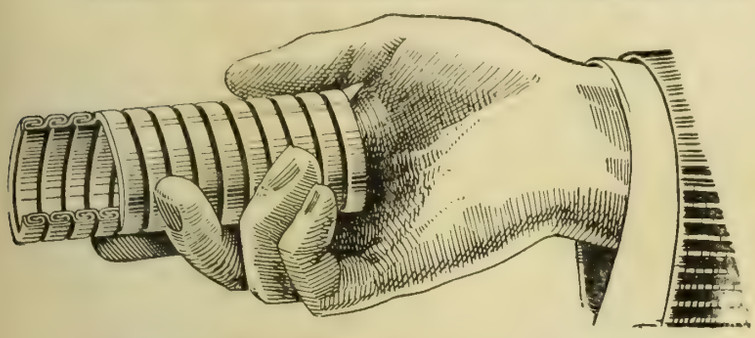

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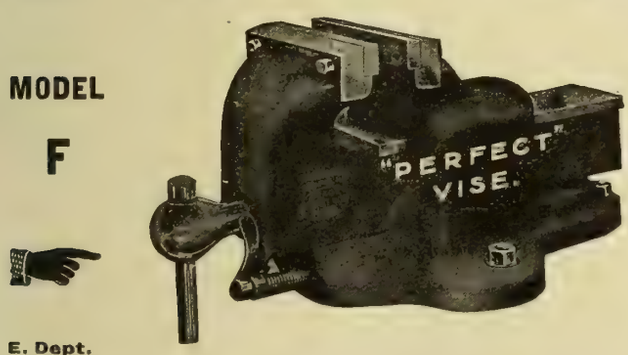

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Unification of Electric Light and Power Distribution.

THE question of coal economy is one of paramount importance at the present time, and its possibilities have been clearly demonstrated by the conservation of the electrical energy developed in large central stations for light and power. It was to this end mainly, apart from its other advantages, to which we think the majority of the country has subscribed after one summer's experience of the Daylight Savings Bill, that this piece of legislation was devoted. The effect of this in diminishing the coal requirements of large towns has been so striking and the saving on this account alone so great, running in many cases to tens of thousands of pounds, that there is little doubt it will become a permanency. Every ton of coal economised means so much more available for the navies of ourselves and our allies. There are still other directions in connection with the generation and distribution of electricity in which immense savings are possible, as was clearly shown in two papers read before the last meeting of the British Association: One by Mr. C. H. Mertz on electric power distribution suggested how economies could be effected by greater unification in the methods employed; the second by Mr. L. P. Sloan giving a record of what has so far been accomplished on the north-east coast. This district has lent itself more readily to centralisation and unification owing to the fact that it is in a district in which enormous amounts of power are required, and that it has also been possible to develop this to a large extent from the heat of blastfurnace and coke oven gases which not many years ago was thrown away. Greater co-ordination between the various power companies has resulted in the attainment of a more constant load, *i.e.*, a better load factor and to a steadily increased demand for power, the amount of energy at present supplied being no less than 343,000 h.p. The fact that this is about one-fifth of the total power used in this district shows how large

a margin remains open for exploitation. The advantages accruing are so manifest that the adoption of electricity has become a more or less automatic process. The district has attracted new industries purely on account of the cheap power available, and led to extensions of existing ones owing to saving of capital which would otherwise have been necessary to instal industrial power requirements. The area now served by the chief electrical power stations on the north-east coast now extends over 1,400 square miles of country, and stretches 70 miles between its northern and southern extremities. The co-ordination of the various systems has entailed a certain amount of time and money to secure uniformity as regards a standard system and frequency, much of which would doubtless have been saved by closer co-operation at an earlier stage. But this only emphasizes the economic aspects of uniformity and of large schemes of electric power distribution, as only by such means can the important items of steady load factor be secured. In this respect, as Mr. Mertz pointed out in his paper, there is great room for improvement. In the past each municipal area has dealt with its wants separately, with the result that the average size of generating machine is only a fraction of what it ought to be for economical working, or what it would be if the district was only a unit in some larger scheme. The consequence is that large power users are choked off the supply to begin with and driven to rely upon their own plant, which, once installed, they are afterwards disinclined to sacrifice unless some compensating advantage can be offered. The growth of small central power stations thus becomes inimical to the general welfare. If the community, he rightly points out, is to benefit by the electric supply industry being given the maximum chance of development, and if the erection of the most economical generating machines in the best possible positions for economical production is to be secured and insisted upon, as it must be, by some central authority, the first aim of which is the establishment in each industrial district of a common inter-connected electrical power distribution system. The attainment of such an ideal is more easy to secure in this country than in others on account of its compact nature, but it does demand co-operation and joint working between different centres in order to secure complete unified systems of electric mains and the erection of the power plants in most suitable locations. The present haphazard method of fixing cycles, voltage, and nature of current are aptly illustrated in Mertz's paper. The metropolis is a striking example. Within the area of Greater London there are no less than 70 authorities and an equal number of generating stations. The average size of units is only 632 kw., while there are no less than 49 types of systems of generation, including 10 different frequencies, 24 different voltages for distribution, and over 70 different methods of charging and price. These defects, which speak for themselves, have been repeatedly dilated upon by reformers, but during the war it is impossible, of course, to expect them to be fully remedied. There is, however, room for improvement in many directions which the present circumstances may be said to favour rather than to oppose. Steps of the kind we allude to have already been taken in Lancashire and Cheshire, where the various authorities, after consultation, have worked out a scheme for interconnection so that various districts may act as reserves or stand-bys to each other, thereby reducing not only the risk of interruption but at the same time increasing the load factor and diminishing power cost. The committee who have had the matter in hand have divided the area into six groups, of which five lend themselves to the scheme, and from estimates that have been got out it is expected that by suitable linking up of various systems the consumption of coal per unit will be reduced from 3·24lbs. to 2·74lbs., a saving of over 16 per cent. At the pre-war price of 17s. 6d. per ton this, it is stated, would represent an annual saving of £82,000, or about 94,000 tons of coal, or at the present price of 45s. would represent over £210,000. This only shows, of course, the potential economies of one district. There are others scattered over the country equally open to improvement and all pointing with equal force to the need for a carefully-thought-out system of national electric power supply.

THE USE OF STEEL CONDUCTORS FOR TRANSMISSION LINES.*

BY H. B. DWIGHT.

ALTHOUGH the tests to determine the electrical properties of steel wires and cables are incomplete, they nevertheless show some attractive possibilities from both commercial and engineering points of view for the use of steel instead of copper for certain classes of work. Already small-sized steel conductors have been used with success in America, and this practice may be extended by a knowledge of the characteristics of large steel cable.

The resistance of an iron or steel conductor is considerably greater for alternating current than for direct current. This is partly due to the skin effect—that is, the crowding of the alternating current to the outside part of the conductor—and by hysteresis or iron losses caused by the alternating magnetic flux in the steel. Although high-grade steel wire proved to be the best conductor for direct current, on account of its higher permeability to magnetism it has a higher resistance to alternating current than a low-grade, less expensive conductor. Thus the cheaper grade was found to be more suitable for alternating-current work. This conclusion is also stated in a recent Bulletin, No. 252, of the Bureau of Standards, Washington, D.C. The Bureau tests show that at commercial frequencies the increase of resistance is approximately proportional to the frequency. It is of interest to note that increasing the number of wires in a cable decreases the reactance, while increasing the size of the wires increases the reactance. Another point brought out by the test is that a large part of the magnetisation is caused by the spiraling of the wires in the cable. If the spiraling of the different groups of wires is properly reversed, the increase of effective resistance, while increasing the size of the wires increases the ing of one layer of wire is clockwise, the next should be counter-clockwise.

The effective resistance and reactance of a steel conductor increases as the current increases. This, however, only continues to a certain point where the effective resistance begins to decrease again. In both cases, especially in large cables, the decrease is very slow and the resistance is maintained approximately at its maximum value for large value of current. This property should prove useful in transmission-line work, for the conductor will have a low impedance to the normal load current, but will have about twice as much impedance to the current flowing in case of a short-circuit. The impedance will also be large in high-frequency surges, caused by switching or lighting. It may prove more economical in certain cases to protect a line against short-circuits and surges by using steel conductors than by installing current-limiting reactors or by increasing the reactance of the transformers. This property may also be used in the case of feeders of direct-current inter-urban railways. If the feeder be a steel cable, it will have low resistance to direct current but high resistance to alternating current. It will therefore tend to dampen out the suddenness of short-circuits and lightning surges, which cause synchronous machines to flash over.

If the feeders are made of steel, and especially if the

* Abstract of paper read at a joint meeting of the Association of Iron and Steel Electrical Engineers and the American Institute of Electrical Engineers, September, 1916.

stranding be coarse, the required protection will be still more complete. Steel conductors would probably be economical only where it is allowable to use bare cable, as the increased amount of insulating covering required for large-sized steel cables, compared with copper ones of the same conductivity, would greatly increase the cost of the former. The higher conductivity of steel for direct current than for alternating current makes the use of bare steel cables for direct-current feeders more economical than for alternating current. A steel cable has about eight times as much resistance to direct current as a copper cable of the same size and seven times as much resistance as a copper cable of the same weight, since copper is more dense than steel. Galvanised steel cable usually costs less than one-seventh as much per pound as copper cables, and so should be more economical, other things being equal.

A large 60-cycle power system in the State of Washington makes use of a considerable quantity of No. 8 iron wire for short tap-offs and lightly loaded branch lines on 6,600-volt circuits, without serious trouble resulting from voltage drop. The iron wire is far cheaper than No. 6 copper. One line built by the company is an example showing that it may be profitable to supply a surprisingly small load at a distance of several miles. This line is 10 miles long and was originally built with No. 8 copper-clad steel to supply a 50 h.p. load at 6,600 volts. The line afterward carried 110 h.p. for some time and was later changed to No. 6 copper in order to have a capacity for a still greater load. An example from Minnesota shows the use of a somewhat larger steel conductor. This line operates at 40,000 volts 60 cycles, and is 20 miles long. No. 4 galvanised steel cable made of three wires is used. The load is about 300 kv.-a.

Besides being cheaper than a copper cable for small branch lines, the steel cable has the advantage of being mechanically stronger and less liable to be burned through by arcs. The steel is therefore of greater reliability at times of wind storms and at times of electrical breakdowns or trouble. Steel cables are subject to the disadvantage that their useful life is shorter than that of copper cables, especially near the seashore, where galvanised steel is more quickly oxidised.

The price per pound of copper cable may be assumed as being ten times that of galvanised steel cable. This ratio is a usual one, being approximately true for times when prices of metals are low as well as times when prices are high. From the data available it seems probable, considering a heavy transmission line complete with towers and insulators where an extra weight of steel conductor would be troublesome, the cost will be approximately the same for the two materials. However, there are many cases where extra strength and size of steel cables are advantageous, and so at present the chief attention should be given to the classes of work where steel can show other advantages than merely low cost on a basis of carrying capacity for alternating-current power. On very high voltage transmission lines where the corona limits determine the size of conductors, the steel conductors have an opening for use on branch lines supplying a few thousand kilovolt-amperes on net works of 100,000 volts and higher.

In conclusion it has been shown that large steel cable, if properly manufactured, can be used for carrying alternating current. It appears that the chief opportunity for the use of steel conductors is on branch lines where the size of copper required merely for the electrical loads would be too small to use. However, in all cases steel conductors will be nearly as cheap as copper ones, if not cheaper, and the use of steel will always increase the reliability of the transmission system.

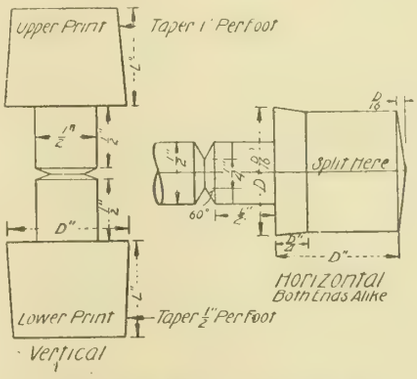
SUGGESTED STANDARDS FOR PATTERN PARTS.

IN a paper read at the recent annual meeting of the American Foundrymen's Association Mr. W. W. Carlson advanced certain standards for pattern parts and recommended a system of colours for parts of patterns to show the finish of the various surfaces of the casting. Thus, if a casting is moulded with the surfaces that are to be machined at the bottom of the mould, there will be less likelihood of these surfaces being imperfect due to slag, dirt, and other impurities, than if they were at the top. Colouring the pattern to indicate which are machined and which are rough surfaces will often enable the moulder to so bed his patterns as to bring the machined surface at the bottom. The following schedule of colours is recommended:—

Rough casting	Yellow.
Machined surfaces	Red.
Core prints	Black.
Pattern joints	Natural shellac.
Pattern boards	Black.

These colours, the author says, may not be ideal but they fill the purpose admirably. In a modified form they are already in use by steel manufacturers, and so he feels it would be an easy matter to settle on some one plan that would soon become generally used. The objection that is sometimes put forth against colour schemes is that they add to the expense, yet every pattern worthy of the name should be properly coated to protect it. The expense of this coating is, he added, a small percentage of the total cost of the pattern; the additional expense of the added colours is slight and disappears when the advantages gained are considered.

Another suggested system of standards is that of core prints. The accompanying illustration shows the system adopted in the shops of the Kansas State College. As will be noted, the vertical core prints have different tapers for the upper and lower ends. This taper is found to be sufficient but not excessive, and it is believed it will fit all average



D	L	D	L
3/8"	3/8"	1 7/8"	1 1/2"
1/2"	3/8"	2"	1 1/2"
5/8"	3/8"	2 1/8"	1 1/2"
3/4"	1/2"	2 1/4"	1 1/2"
7/8"	1/2"	2 3/8"	1 1/2"
1"	5/8"	2 1/2"	1 1/2"
1 1/8"	1/2"	2 5/8"	1 1/2"
1 1/4"	5/8"	2 3/4"	1 1/2"
1 3/8"	1/2"	2 7/8"	1 1/2"
1 1/2"	1 1/4"	3"	1 1/2"
1 5/8"	1 1/4"	3 1/8"	1 1/2"
1 3/4"	1 1/4"	3 1/4"	1 1/2"

conditions. The shanks are all turned to the same diameters so that certain prints can be removed and others substituted of whatever size is desired. The author enumerates commendable points of the prints as follows: (1) There is a saving of time in making patterns by having core prints on hand. (2) There is a decrease in expense due to the fact that apprentice boys or low-wage help can be used instead of the more highly-paid pattern-makers. (3) Ease of changing the size of core prints on a pattern for pulleys and in various places where varying holes are required, is of value. (4) Since the tapers on the vertical prints are the same it is much easier and surer to secure properly fitted cores in the core prints. (5) As will be noted, the horizontal print has an increased diameter next to the pattern to aid in avoiding crushing the sand next to the mould when the core is put in place. (6) There results an increased rate of production and satisfaction to the workman by having definite written instructions for the men to follow.

The accompanying standard list gives only up to 3¼in. in diam. with a length of 1½in. This length prevails up to 4in., where the length changes to 2in., which continues to 6in. diam. At 6in. the length becomes 3in., and at 8in. the length changes to 4in.

The Society of Engineers.—An ordinary meeting will be held at 5-30 p.m. on Monday, November 6th, at Caxton Hall, Westminster, S.W., when a paper entitled "Heating and Ventilating Private Dwelling-houses," by C. T. Alfred Hanssen, F.S.E., A.M.Inst.C.E., will be read.

WORKS ORGANISATION.*

BY A. D. C. PARSONS, B.A., EDWIN L. ORDE, AND G. H. TWEDDELL.

AT the present moment the problem of works organisation is one of extreme importance. No one can say definitely what the conditions, as affecting the engineering trade as a whole, will be after this great war has come to an end; but it seems certain that international competition will be keener than ever, as soon as those countries at present at war have had time to recover from the strenuous exertions they are now putting forward. If the war ends in the way in which we all believe it will, the possibilities offered to the engineering trade of this country cannot be taken full advantage of unless the industry is organised in all its branches so as to enable it to hold its own in those markets previously supplied by the countries who are now our enemies. We in this country are undoubtedly far behind Germany in organisation generally. There probably never was a better example of highly-developed organisation than the German nation before the war, and this naturally affected those industries, such as engineering, which were destined to play such an important part in war. The organisation of any big industrial

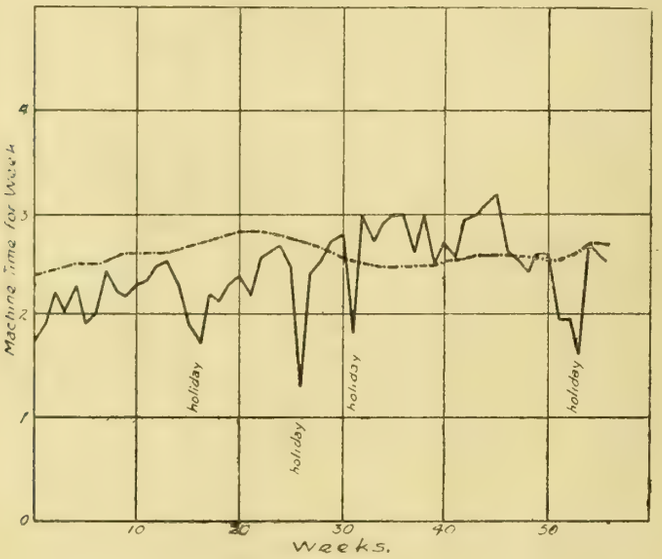


FIG. 1.

concern is the work of years; it cannot be hurriedly devised; nor can it be expected to work smoothly without the expenditure of a great deal of thought, patience, and constant attention. It is of no use having any one section of a business beautifully organised if other sections have no proper scheme of organisation, for the results of the whole are almost certain to degenerate and be gauged by that section in which the organisation is least perfect. It is therefore necessary to have some homogeneous scheme in which all the various departments will work together smoothly, devised with the one aim in view, namely, to make the concern a paying and successful enterprise. In this paper it is proposed to divide the question of works organisation into three main parts covering: (1) manufacturing, (2) costing, and (3) selling of the works product.

PART I. MANUFACTURING ORGANISATION.

BY A. D. C. PARSONS.

In dealing with the manufacturing side of works organisation it is of course impossible to lay down any definite scheme which will be applicable to all lines of manufacture. The system adopted must necessarily depend upon the nature of the product and the size of the works employed on its manufacture. There are, however, some features which will always stand out as essential in any business run on successful lines. Manufacturers in this country labour under a considerable disadvantage as compared with those say in America, in that the manufactured product is not as a rule so standardised. In the latter country it is usually the case that the manufacturer has a much greater say in the details of his product than they do in this country. The conditions are different; labour is more expensive, and therefore the demand for mechanical power is greater.

We will, however, first consider the question of those works where the product is not of a particularly standard type, and then take the case of some of the more elaborate systems of organisation now adopted in the United States. We must assume that the design of the apparatus which the works has to manufacture is thoroughly sound, so that when the drawings are complete there will not be numerous alterations to be made to the article during the time of its manufacture. If this is not the case the general organisation of the works is bound to be seriously affected. It is not, of course, supposed that such alterations will never occur; new designs embodying improvements in any go-ahead concern will be continually put forward; but with a good designing staff such changes after the design has been approved of will be reduced to a minimum. Much progress in this direction will be made if the draughtsmen would always consider what can be easily machined and manufactured in the shops, and what is liable to cause difficulties. Also to specify materials and details which they know to be kept in stock. In other words, the design should, so to speak, be built by the draughtsmen before the drawings are sent to the shops. Although this is the ideal there will be many cases when the shops consider that some alteration might be made with advantage, and it is only by continually following up such suggestions that the ideal state is ever approached. The result to be aimed at is quickness of manufacture, which ensures getting the maximum production out of the plant, thus lowering the overhead or establishment charges, and cheapening the production.

General Lay-out of Works.—The general lay-out of works will necessarily have a great effect on speed of manufacture, and it is in this respect that new works have a great advantage over some of the older ones. In modern up-to-date works the machinery departments form main parts, the assembling and the testing departments for any particular type of machine are usually adjacent to one another, and, if possible, continuous. This obviates any unnecessary handling of material, and also allows the foremen in charge to be in constant touch with one another without leaving their departments. Furthermore, when these departments can be arranged so as to be continuous the same group of overhead cranes can serve them all, thus preventing any unnecessary dismantling of the machines when placing them on the test-bed. Also, should the length of the shop permit it, the painting and dispatch departments can with advantage be made continuous with the testing department. If this can be arranged it will mean that the raw material is delivered at one end of the shop, is manufactured and tested in that aisle, and is dispatched completed at the other end without retracing its steps.

In like manner the detailed departments will also be placed as near as possible to those departments which they have to supply. These detail departments will in many cases be laid out to manufacture some particular details required in large quantities by the factory. They will therefore be equipped with a number of machines of the same type controlled by a foreman expert in this line. It is obviously more economical to have these machines grouped in one department instead of having them scattered over the works, it also has the great advantage of preventing any uncertainty arising as to where a particular class of work will be carried out. These detail departments will have to be supplied with their raw materials, such as castings, bar, or plate, and therefore the stores containing this raw material must be conveniently placed, to ensure an easy supply with a minimum amount of handling.

Possibly the most convenient way of dealing with the question of the manufacturing side of works organisation is to consider each section of the works in the order in which these sections will have to deal with any particular contract, and then to discuss some system of production designed to follow through the manufacture methodically. Two natural divisions present themselves, viz., (1) preliminary to receipt of contract, (2) after the contract has been obtained.

Preliminary Work prior to Receipt of Order.—Before an order for any particular machine is received a considerable

* Paper read before the North-east Coast Institution of Engineers and Shipbuilders.

amount of preliminary work has to be done to enable an estimate to be prepared in accordance with the specifications issued by the intending purchasers. To do this the estimating department must be supplied with the necessary information by the designing staff to enable the former to determine what will be required in the way of new tools and special appliances to carry out the manufacture of the plant. They will also require to know with considerable accuracy the amount of labour and material necessary. The majority of specifications are necessarily somewhat lengthy, and it is therefore essential that the estimating staff should be thoroughly competent to investigate all details, and to foresee any possible causes of trouble and expense which the firm might be put to should any of these be overlooked.

Order No. Destination Date of Order 5 3 1914 Date of Test 5 10 1914 Date of Delivery 2 11 1914

Type 3000 K W Impulse Reaction Turbo Alternator
Complete with Surface Condenser, Air & Circulating Pumps

NAME OF PART	No of	No	Drawings No	Drawings Due	Drawings Received	Patterns Comp	Patterns No	Patterns Issue	Patterns Rec	Material Make	Material Order No	Material Ordered	Material Due	Material Rec	Machine Shop Work Due	Machine Shop Work Comp	Remarks
Turbine Bedplate or Pedestal	1	1	12228	30 3 14	26 3 14	28 3 14	791 J	6 6 14	20 5 14		77544	20 5 14	4 7 14	16 7 14			
Cylinder Foot Guides	2	1	.	.	.	.	744 B	.			77545	.	.	9 6 14			
Cylinder Cover Steam End	1	2	11710	25 3 14	6 4 14	8 4 14	758 U	9 5 14	6 5 14		77310	6 5 14	9 6 14	5 6 14			
Cylinder Bottom Steam End	1	2	.				758 T	.			.			29 6 14			
Cylinder Centre Top	1	2			None												
Cylinder Centre Bottom	1	2			None												
Cylinder Cover Exhaust	1	2	11710	25 3 14	6 4 14	8 4 14	750 T	9 5 14	6 5 14		77303	6 5 14	9 6 14	12 6 14			
Cylinder Bottom Exhaust	1	2	.	.		.	750 S				.		.				
Steam End Keep	1	2	11716	25 3 14	18 3 14	21 3 14	778 U	9 5 14	12 5 14		77107	12 5 14	6 6 14	30 6 14			
Central Keep	1	2			None						.						
Exhaust End Keep	1	2	11716	25 3 14	18 3 14	21 3 14	773 W	9 5 14	1 4 14		76701	1 4 14	29 4 14	22 4 14			
Baffles for Keeps	6	2	.	.		.	782 G	16 5 14	18 6 14		78018	18 6 14	25 7 14	7 8 14			
Cylinder Neck Glands	4	2	11714	.	.	.	773 X	9 5 14	1 4 14		76703	1 4 14	29 4 14	9 5 14			
Cylinder End Plugs	2	2	11715		.	.	778 Y	.	13 6 14		77810	13 6 14	18 7 14	28 7 14			
Cylinder Relief Valve	1	2	9456		2 4 14	3 4 14	529 C	16 5 14	20 5 14		76577	20 5 14	26 14	20 6 14			
Cylinder Blades		2	13096	16 5 14	30 5 14	4 6 14									11 7 14		
Spindle Blades		6	.		.	.					.				.		
Spindle	1	6	11714	1 5 14	23 5 14	25 5 14					76529	19 3 14	23 5 14	14 5 14			
Spindle Discs	1	6	.	.		.					.		.	.	.		
Steam Stop Valve	1	6				10 3 14					76576	12 3 14	18 4 14	18 3 14			

FIG. 2.

In determining the time promised for delivery the capacity of the works and the number of orders on hand must be carefully considered. Guesswork must be as far as possible eliminated, for if the manufacturer can live up to these promises his reputation will be considerably enhanced. It will be useful, therefore, to have some graphical representation of the fullness of the factory. Fig. 1 shows one way of arriving at this. The ordinates in Fig. 1 may be in any convenient unit such as £'s, h.p., kw., or number of machines, but in many cases the most convenient unit will be "Machine time per week." In the majority of works each machine-tool will be rated at a certain figure per hour, depending upon the capital expenditure on the tool, and all work done on any particular tool will be charged with that rate per hour.

The estimating department will know with considerable accuracy the amount of machine time necessary in the manufacture of a plant, and if by means of some equation this can be spread out over the time during which the order is going through the works, an approximate idea can be formed as to how much machine time will be expended per week. This then is done for each order and the results are superimposed on one another, thus obtaining a curve shown by the continuous line in the figure. It is also possible to plot the total actual machine time used in the manufacture of these orders, thus giving a fair idea as to whether the output bears a satisfactory relation to the amount of work actually on the books. The latter curve is shown dotted, and from this a measure of the capacity of the works can be found by averaging up the actual machine time per week over the period of say one year.

Diagrams of the nature of Fig. 1, rough though they may be, should prevent totally unreliable promises being made so far as the delivery of orders is concerned. To manufacture an article cheaply and efficiently it is necessary that every part required to make the whole shall be ready by the time it is wanted. If details are not to hand when they should be it means that the work of assembling these details is delayed, and consequently the organisation of that department greatly diminished. It is therefore in this direction that organisation plays such an important part, and in order to follow through a scheme which has as its aim the prevention of such delays, it is proposed to trace an order through the various departments of the works from the time it is received to when it is dispatched.

Supplying the Manufacturing Information.—After the contract has been obtained it is best to determine how long can be given to the various operations, such as drawings, patterns, obtaining raw material, such as castings and forgings, machining of these parts, completion of details, assembling, testing, &c. One very convenient means of doing this is to lay out a rough time table covering the various operations, starting with the delivery date and working backwards to the date of receiving the order. This is, of course, only approximate; but after taking into consideration the present condition of the works, it can be estimated from past experience how much time these various stages in the manufacture will occupy. Any surplus time, should there be any, can be apportioned to those departments where there is likely to be any congestion.

We have now determined how long the drawing office can be given for completing full working drawings. From this a list can be prepared which is sent to the drawing office specifying when full manufacturing information for the various parts must be sent into the shops. In addition to the full working drawings, this information should consist

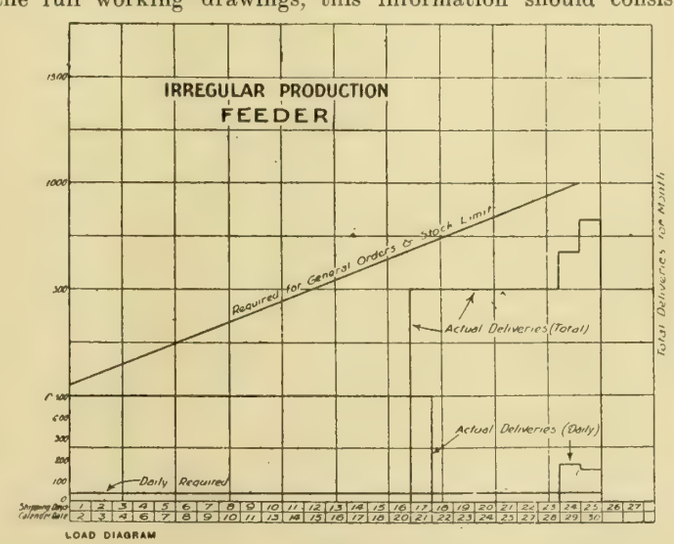


FIG. 3.

of a full detailed specification giving particulars of drawing numbers, pattern numbers, and complete details of all parts. The necessary numbers of copies are taken from this specification and each department concerned in the manufacture receives a copy. As soon as the design is well advanced, the drawing office (or in some works the purchasing department) will send out enquiries for such forgings, castings, raw material, and completely manufactured parts necessary for the manufacture of the machine. On receipt of tenders from the outside suppliers, the official orders will be sent out and these will state clearly by what date the materials must be delivered.

Production Department.—The specification sheets furnished by the drawing office should pass through the produc-

tion department on their way to the shops. It is the work of this department to see that all details required, whether manufactured in the works or supplied from outside, shall come to hand when required by the machining or assembling departments. Some method must be adopted whereby all material can be kept trace of in a systematic way, for on this will depend the satisfactory feeding of the factory. The general time table of manufacture is based on the expected

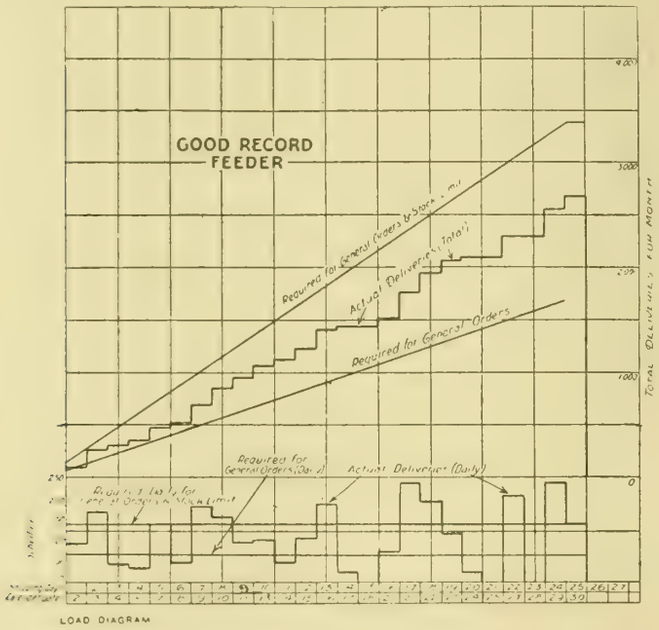


FIG. 4.

delivery of the material, and should this be much overdue the time given for the completion of the various parts must be seriously interfered with. It is therefore essential that this work shall be done well and efficiently. In any system designed to accomplish this, the aim must be to anticipate any possible cause of delay in obtaining material, whether due to lateness in ordering or delay in delivering by suppliers.

It will be convenient to keep a record arranged in a suitable form enumerating in as much detail as is thought necessary those parts required for each machine. From this record the production department can see at a glance how the material is coming in, what remains to be ordered, and what requires to have pressure applied to urge forward delivery. Fig. 2 illustrates one form of a record of this sort. As soon as the order is placed those columns indicating when the drawings will become due can be filled in by the aid of the rough time table which has already been laid down for the particular machine. This can be used by the production department in keeping the drawing office advised of any drawings which are unduly delayed. As soon as the drawings are complete they are forwarded to the works viâ the production department, when the other columns under this heading can be filled in. The specification made out from the drawings will follow very shortly, and from this the first two columns under heading "pattern" can be completed, and so on throughout the table, each column having the information recorded as the work proceeds.

The results shown in Fig. 2 are taken from an actual case, and it will be seen that the results obtained agree very closely with the estimated dates as to when the drawings, patterns, and material should be received. Furthermore, when a number of such records for different machines have been collected the production department has in its possession valuable information on which to base deliveries for future machines.

When the specifications have been received by the works it is necessary to have some system whereby each foreman can at any time see what his shop has to complete and by when. It is, however, important that the clerical work should be kept down to the minimum. In those departments engaged in machining large pieces there is comparatively little difficulty, for the number of parts are few and move slowly. Here the foreman will probably find that the specifications marked with the date when each piece must be complete will prove sufficient. In detail departments it is however an entirely different matter. The parts may be small and very numerous: they may also be required at very different periods. It is here where delays may prove serious, for the final assembling of the machine will be much interfered with should any essential part be wanting when required.

Detail or feeder department will therefore usually require considerably more attention than other sections of the works. In these departments there must be some means of tabulating the work in hand in the order in which it is required, so that at any time the foreman will know whether he is up to date, what orders are overdue, and what amount of work he has ahead of him. The need for this is obvious, for without an index of the kind referred to, it will be necessary for him to spend a considerable time out of his department, in order to find out from those departments which he has to supply what they are requiring at the moment and what their needs will be in the near future. Anything which can be done to obviate the absence of a foreman from his department is a direct gain in efficiency, for no part of the shops can be expected to work to the best advantage if the foreman is continually elsewhere. A convenient form in which to lay out an index of this sort is to have a book, or cards if these are preferred, so that each week has a certain space allotted to it. As the specifications are received marked with the date by when the material has to be complete, the details are entered as concisely as possible under the week in which they become due. As the work is completed the index is marked off, so that the uncompleted items stand out conspicuously.

Assembling Department.—When we come to assemble all the manufactured parts to form the complete machine, there should be no difficulty if the feeder departments have delivered their details by the time specified. It is, however,

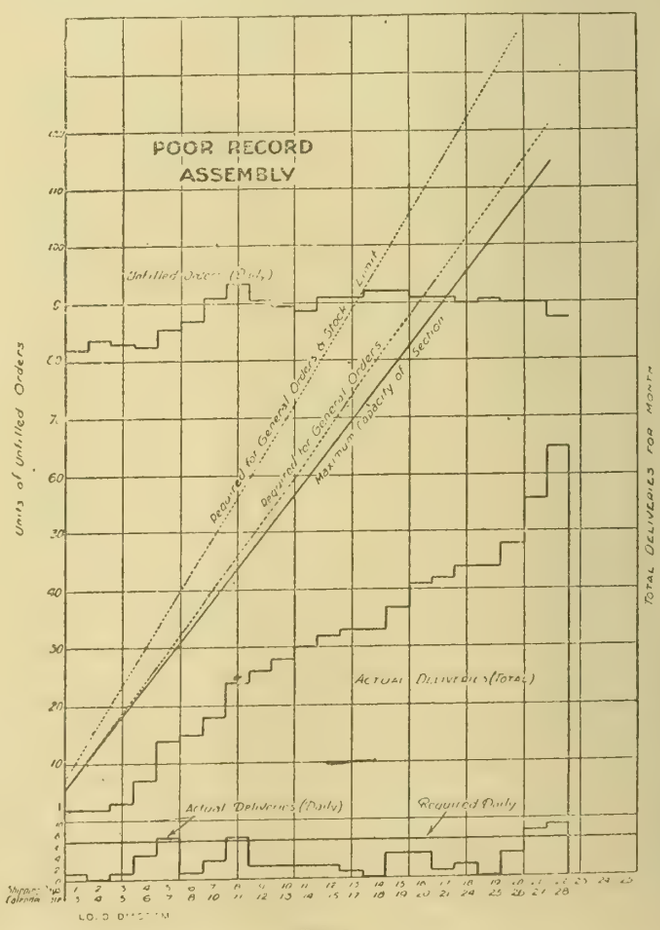


FIG. 5.

here that all delays which may have occurred in completing these details are reflected as a much more serious delay in the finished article. It is therefore in these assembling departments that the fruits of organisation are more visible than almost anywhere in the factory. If these delays are prevented the output is greater, it is assembled more cheaply, and the men work better if the supply of material is constant and is received when required. Furthermore, it is far from

satisfactory and decidedly inefficient to have a large number of partly assembled machines lying about the floor, all of which are held up owing to the lack of some small part. To prevent this from happening, the foreman naturally does not like to commence assembling the details until he is sure of being able to carry the work through without stoppage. He must therefore have some means of ascertaining exactly how the material stands for any particular machine. This information can be obtained by referring to the specifications, which must, of course, always be kept up to date, as regards completed material lying in the main or detail stores, and all stock parts which are supplied directly by the stores. The method usually employed for keeping these specifications posted is for the detail departments to forward to the assembling sections receipts for all completed materials as soon as these are handed over to the stores; some similar method also being adopted for those parts delivered complete from outside sources and for stock material not manufactured in the works.

Stores.—Although the manufacturing feeder departments play such an important part in the organisation of the factory, the various stores for raw materials and manufactured parts supplied from outside sources, comprising as they do hundreds of items in various forms, are absolutely vital to the successful feeding of the factory. These stores, too, will contain stocks of expensive materials, which it will be necessary to keep down to the lowest possible limit. It is therefore usual for the storekeeper to keep a systematic record covering all items in his stock and specifying the maximum and minimum allowed, the ordering quantity and the ordering level. This record can be kept in a loose-leaf ledger or on some card index system, and as material is given out the details are entered in the ledger, debiting the order number for which the material is required with the quantity supplied.

Manufacturing of Standard Apparatus.—In what has already been said it has been assumed that the works product is not manufactured chiefly to standard designs; when, however, the factory is principally employed in turning out an article in large numbers made to an improved design, the system may require some modifications, and possibly some elaboration which would not be warranted where the output is not standard and where the designs are frequently changing. In factories dealing with this kind of manufacture the sales will, to a great extent, be made straight from a price list. Deliveries will also to some extent be standardised for any particular size and type of machine. To obtain these deliveries it is essential that no time be lost in getting the manufacturing information into the works. On receipt of the order the designing staff will have to decide whether the standard type of machine is capable of fulfilling the requirements of the contract, and if so will pass the order on to the specification clerks, who will make out specifications for passing on to the works.

These specifications will also probably be standardised and it will only be necessary to select those specifications applying to the order, to fill these in for the required number of machines, and to forward them to the works viâ the production department. These specifications, together with the detailed drawings which will already be in the works, will constitute the entire manufacturing information. To expedite the completion of this information in the minimum time possible various printed forms are used so as to save any unnecessary clerical work. To give examples of these forms and to describe their details would be of little general interest; but in any system adopted care must be taken to guard against the tendency of building up a system of forms only, and so eliminating the human element of interest and responsibility. If such care is not taken there is a great danger of the whole system developing into so much waste paper and the work being completed before the system designed to assist in its manufacture can come into use, in which case it will be much more likely to hinder than assist production.

The production department will distribute the orders and specifications throughout the works as previously, each being marked with the date by when the various components have to be completed. In most cases a large portion of the details required will be manufactured to stock, and each feeder department will therefore have to see that these stock parts are put through in suitable batches so that they can meet the demands made upon them. This work will be regulated by the production department under the supervision of some higher authority, to ensure that the stock does not reach too high a level, and so tie up too much capital, or fall too low and so jeopardise the delivery of the final product.

As previously stated, it is in the assembling department that the efficiency of the works in production is best gauged. It is, therefore, well to have some method whereby the management can see at a glance whether the organisation of the works as a whole is such as to ensure the factory producing the right quantity at the right time.

A large American works employed in the manufacture of all kinds of electrical machinery, and where the output of machines and accessories, all more or less standard, is large, has devised a very complete system for accomplishing this. Graphical records are kept of the output of the feeder and assembling departments. These records are known as load diagrams, and contain curves indicating for each day the total number

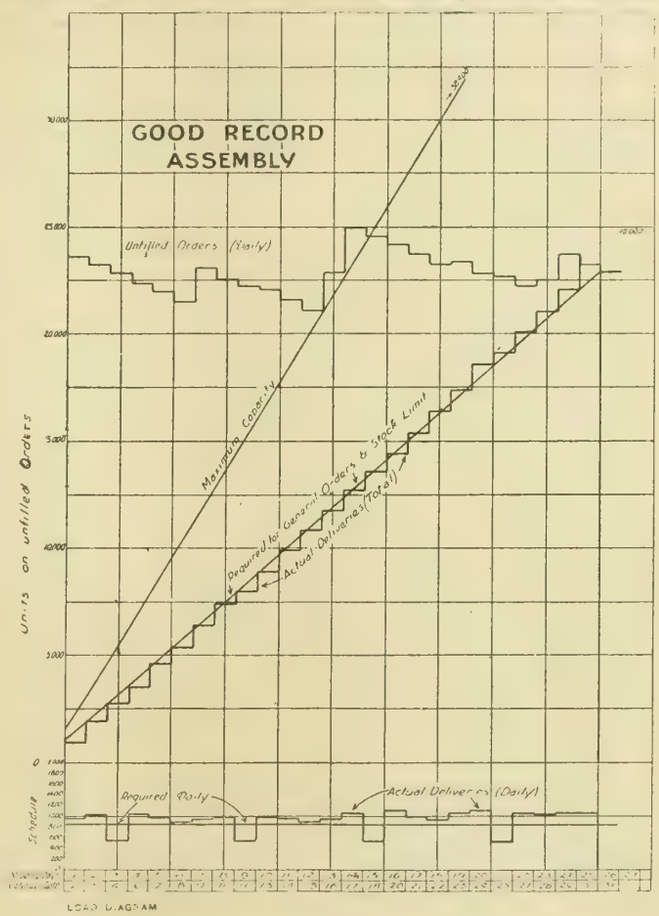


FIG. 6.

of units on order not delivered, the number of units wanted each day, and the number of units actually delivered each day. Results thus obtained are shown in Figs. 3 and 4 for feeder departments, and in Figs. 5 and 6 for assembling departments. In examining these it can be easily seen whether any section of the works is turning out what is required from it, or whether it is lagging behind.

In addition to these load diagrams, another chart is made out showing how the dates given to the customers are met. This is known as the delivery efficiency chart, a typical case being shown in Fig. 7. On this chart are plotted curves showing the daily percentage of dates kept, the average percentage of apparatus shipped on time for the past 30 days, and the percentage of overdue orders on hand. In some cases this chart is amplified by adding curves showing the percentage of orders overdue by varying amounts such as 5, 10, or 20 days late. Copies of these charts are circulated through the works, with the result that very considerable interest is taken by those departments concerned, and a certain amount of friendly rivalry is set up between them.

In such works as we are now considering the detail and assembling departments naturally specialise to a much greater extent in the manufacture of certain parts than in the case of those works where the product is not so standardised. This will also entail a more systematic grouping of certain classes

of machines, for the tendency is that each detail will be made in large quantities which on completion will be turned into stock and from which the assembling departments will draw.

From the nature of this manufacture it is obvious what an important part will be played by jigs used for these standard details. Without these jigs, on the design of which a great deal of ingenuity is expended so as to make them easily and quickly handled, it would be quite impossible to manufacture cheaply, nor could the great advantage of interchangeability and the supply of spare parts be attained.

Conclusion.—In this section of the paper the author has endeavoured to point out some of the essential details necessary in the manufacturing side of works organisation; but no matter whether the works are large or small, whether the apparatus manufactured is standard or special, the human element is bound to play an all-important part. No works

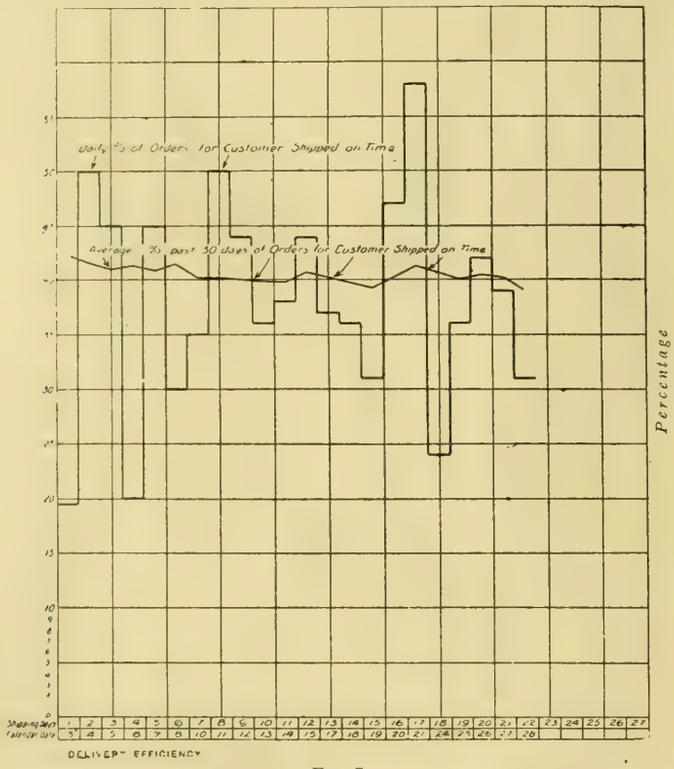


FIG. 7.

can ever be independent of this factor, indeed the co-operation of individuals and departments is so vital that it may well be considered as the foundation of any system. Furthermore, heads of the departments must be men of broad mind, capable of handling those under them, so as to encourage them to have real interest in their work, to treat their profession as something in which they can have real pleasure and not just as a dull monotony. The result of this will be that individuals in subordinate positions will gradually be found capable of taking more responsibility, so that when the time does come for the heads of the departments to move on into other positions, there will be someone so trained to carry on the organisation of the department. Much might be said about co-operation, but it is so obviously necessary, and it stands out so conspicuously in every walk of life, that it need only be mentioned in connection with the present question. Unfortunately, however, one so often finds that individuals and departments are not worked at their highest efficiency, due to the lack of this essential. Without perfect co-operation the effectiveness of any system, no matter how good it may be, will be greatly reduced.

(To be continued.)

Board of Trade Commercial Intelligence Committee.—A meeting of the Advisory Committee of the Board of Trade on commercial intelligence was recently held in London. Among other matters considered, were proposals for the amendment of the existing law relating to patents and designs; proposals for the dispatch of a special Commercial Mission to investigate the conditions and prospects of trade in Spain and Portugal; and questions relating to British trade with Russia and Italy, and the employment of foreigners as commercial travellers.

CORROSION OF STEEL SHEETS.

AT a recent meeting of the American Electrochemical Society a paper by E. A. Richardson, Warren, and L. T. Richardson, entitled "Observations Upon the Atmospheric Corrosion of Commercial Sheet Iron," was read. As a result of their investigations the authors arrived at the following conclusions.

Taken as a whole, the results indicate that copper-bearing steels are, without doubt, decidedly superior to any of the other materials tested. The remaining materials may be divided roughly into two classes, one class including the ordinary steels (Bessemer and open-hearth) and the other class the commercially pure irons and the copper-bearing irons. Charcoal iron is classed with pure irons. We have obtained results in another test which would indicate that the resistance of wrought iron to corrosion is due to the purity of its iron and not to slag inclusions. In addition, it was noted during the present test that charcoal iron appeared to corrode in very much the same way as pure iron.

In regard to the steel-iron question, it is noted that the pure irons (including charcoal iron) are superior to steel. It is believed that this superiority is due to the purity of the iron, or to some combined effect of manganese and copper.

The results obtained in regard to the effects of mill scale do not agree with the results obtained by others. They indicate that with steels which rust rapidly mill scale is a stimulator of corrosion. On the other materials tested the mill scale has exerted a protective action. We have no explanation for this.

The important feature of the results, however, is that it substantiates the claim made in several other publications that the addition of copper to steel in amounts of about 0·25 per cent. causes a remarkable increase in its ability to resist atmospheric corrosion. In the present test the addition of about 0·25 per cent. copper to Bessemer or open-hearth steel has resulted in an increased resistance of 300 or 400 per cent.

The addition of copper to pure iron also results in an increased resistance to corrosion, but to no such an extent as the addition of a similar amount to steel. The addition of about 0·25 per cent. copper to a commercially pure iron results in the useful life being increased by about 20 per cent.

We have been unable to determine the reason for this effect of copper in reducing corrosion. It is believed, in view of the fact that the copper exerts a greater influence in steel than in iron, that it must be due to the combined presence of copper and manganese, since the chief difference in the iron and steels under consideration is in the manganese content. It may be that the copper eliminates a harmful effect of manganese, or it may be that it is some combined effect of these two elements that acts as a protection to iron. The writers are inclined to believe that it is the latter cause.

Tests made by D. M. Buck indicate that copper even up to 0·10 per cent. added to low manganese materials increases their resistance to corrosion but little. Ordinary steels containing about 0·40 per cent. manganese, but no copper, are very poor as regards resistance to corrosion, but additions of copper to such steels result in a greatly increased resistance. A maximum resistance is reached with about 0·25 per cent. copper. These results were also confirmed upon full-sized sheets of the same materials.

The writers believe, in view of these results, that the resistance of pure iron to corrosion could be increased by the addition of both manganese and copper and that additions of manganese to pure iron or steel, even up to 3 or 4 per cent., or more, with a corresponding increase in copper to produce a maximum effect, should give a material more resistant to atmospheric corrosion than the copper steel now on the market. Also, some interesting results might be obtained by substituting for manganese in copper-bearing steels or irons, chromium, vanadium, tungsten, or molybdenum.

Summarising the authors state (1) Copper-bearing steels are decidedly superior to pure iron, steel, or charcoal iron. (2) The addition of copper to pure iron increases its resistance to corrosion, but to no such an extent as similar additions to steel. (3) Charcoal iron and pure iron are superior to steel as regards resistance to atmospheric corrosion. (4) Charcoal iron is very similar to pure iron in its resistance to corrosion. (5) Copper is believed to decrease corrosion due to some mutual influence of manganese and copper. (6)

Additions of larger amounts of manganese and copper to pure iron or steel are suggested as well as additions of copper-chromium, copper vanadium, copper tungsten, or copper-molybdenum. (7) Mill scale stimulates corrosion in rapidly rusting materials and retards it in slowly rusting materials.

THE USE OF BORINGS IN CUPOLA OPERATIONS.*

BY JAMES A. MURPHY.

THE melting of iron borings and even steel chips in the cupola for the double purpose of reducing mixture costs and bettering quality is not by any means a new theme for foundrymen to discuss, for in one form or another they have been successfully melted for many years, some methods being more successful and economical than others. About 30 years ago a patent was granted to Asa Whitney, of Philadelphia, covering a method of melting borings in wood boxes. This method is in use at the present day by some leading foundries, and the results, from a quality point of view, seem to warrant its continuance. Many other methods are employed, some of which have been subjects of exploitation, and several patents of doubtful value have been granted. A number of the methods indicate an ignorance of the principles involved, while others are freakish, and not a few are pure fakes.

The melting of chips loose in the cupola has been tried both alone and in combination with regular mixtures with very indifferent results. When melted alone the necessary heat will not penetrate the mass, the under and outer edges of the charge only being melted to varying depths depending on the quality of the fuel, the blast pressure, and the thickness of the charge. When chips are charged promiscuously with the pig and scrap, the pyrotechnical display at the door and top of the cupola stack indicates the destruction of the elements of which they are composed. Both of these methods have long been abandoned. A few foundrymen, however, lay a thin bed of borings on the cupola bottom. The melting iron coming down on the borings melts and absorbs them, but this is done at the expense of heat that may be badly needed by the iron. I consider this method for either chips or other small particles hazardous in the extreme where particular castings are made.

In the middle eighties a foundryman in Scranton, Pa., conceived the idea of filling old powder cans with these borings and charging them into the cupola the same as pig and scrap. The method was said to be very successful and was continued as long as the supply of old cans held out. For years, nothing was found for a substitute except wooden boxes. Along about 1904 Stanton Griffith, foundry superintendent of the Fairbanks-Morse Company, Beloit, Wis., was experimenting with the melting of borings in various kinds of containers, none of which was as satisfactory as Mr. Griffith desired. As Newton's discovery of the law of gravitation was accidental, so the method that I am going to describe was accidental to Mr. Griffith through the obstreperousness of a tomato can that found its way into the household furnace where it remained intact for some time, a decided obstacle to good and thorough combustion. Its remarkable state of preservation after going through a fierce fire certainly classed it as an ideal container for melting borings, but as its size was against it a similar but larger can was made from regular lengths of stove pipe, crimping the can in at each end when full.

This method proved so successful that I was attracted by it, and from the results from several tests that I made, I concluded that no other method gives as good, as economical, or as reliable results. The stovepipe lengths will hold about 50lbs. It is preferable to use either a wood, iron, or steel disc for the top or bottom of the cartridge. The containers can be filled at the machines by machinists' helpers at very little if any cost, as the borings must be taken away anyway. The cost of preparation for the cupola is about 10s. per ton.

On three different occasions I melted 10 tons of these canned borings alone, using a blast pressure of from 9ozs. to 10ozs., our regular blast being from 14ozs. to 16ozs. All three of these heats showed a loss of less than 2 per cent., which seems remarkable. The charges were carefully weighed under my own supervision. A 10-ton ladle was weighed on a crane scales and then placed under the cupola spout, and when the contents of the cupola were run into it, it was weighed again with the above results.

The iron in each case was white and in no way fit for commercial machinery castings. It showed no tendency to stick to the ladle, but was hot and fluid. A 6in. by 6in. section poured from the ladle was white all through, not a trace of graphitic carbon being visible near the centre. The melting of borings in cans or cartridges is being practised by a large number of foundries engaged in both light and heavy work. There is no patent on the process. It is beyond question a thoroughly successful method.

In 1908 a patent was granted to Walter F. Prince, for melting borings in a vertical tube or casing having a higher melting point than the chips. The method at first was open to many serious objections, some of which have since been removed. Borings can be successfully melted by this method, but it lacks what might be called mobility, as all the borings are only in one part of the cupola, in a vertical column, with fuel only partly surrounding it, whereas, with the cartridges, they can be distributed among the charge, giving a better mixture and ensuring more even melting.

The briquetting of borings by the German method, that is, subjecting them in suitable moulds to great pressure, is a successful method, but the cost is high and there is a considerable melting loss. It is said that the breaking or spalling of the corners and edges of the briquettes represents a great loss. The briquetting of borings through the use of cement, canna pitch, or any other wet binder, is without question a great failure. The rapid generation of oxygen when moisture comes in contact with the borings soon leaves only a lump of rust to put in the cupola, and when used in this way is productive of bad castings, as pinholes and so called blowholes are prevalent. The melting loss by this method I found by experiment to reach as high as 60 per cent., while the resultant metal was bad. Castings poured with it for experimental purposes were very unsound and literally honeycombed with holes, while on the other hand, castings poured from similar metal, taken from a ladle that was filled from the cartridges was sound all the way through and showed no signs of pinholes or any other unsoundness. As a practical proposition the use of borings in binder bound briquettes is a failure. The briquettes made under enormous pressure are satisfactory, but the cost and melting loss are much higher than when melted in cans or cartridges.

The tube method, introduced by Mr. Prince, has very narrow limitations as to the amount used, this being governed by the size of the tube, which of necessity must be comparatively small. If a multiplicity of tubes is used there is great danger of oxidation, as no fuel is underneath them. They can only be placed in one position in the cupola, and that a specially prepared one on the side with a special door cut for the purpose. The attendant labour and waste of filling close to terrific heat is another objection.

With the cans or cartridges no extra labour is involved in the charging floor, and the given amount to be put on any charge can be as evenly distributed throughout the charge as any component part of it. The cost of canning the borings, exclusive of the labour of filling them, is about 10s. per ton. This filling labour should hardly be counted under most circumstances, as the borings must be taken away from the machines, and the helper may as well fill the cans as to use any other receptacles.

Borings melted by this method are a decided strengthener of castings, and tend to give a closer grain. I have used them in various percentages in all kinds of work, from the heaviest parts of high-class machinery down to light automobile castings with unvarying beneficial results.

The cost of wooden boxes is also about 10s. per ton, and the cost of tubes very little less. The cost of briquettes varies greatly. So many variables have to be taken into account and the method is so unreliable that it is not worth pursuing.

* Paper presented at the American Foundrymen's convention, September 15th, 1916.

British-made Magnetos.—According to the "Commercial Motor," all-British magnetos are now being made at the rate of, approximately, 2,000 machines per week, and practically the whole of this production is being utilised for Government work. These home-produced magnetos are being made equal in merit to the Bosch, and in some particulars even better.

INDUSTRIAL LIGHTING BY ELECTRICITY.*

BY FREDERIC H. TAYLOR, A.M.I.E.E., A.M.I.M.E.

To have suggested but a few years ago that the subject of industrial lighting was a matter of supreme importance, one worthy of the special attention of engineers, and for them to devote their time and special efforts to its study, would, indeed, have been amply sufficient to invite a criticism much more cynical than polite. Happily, however, the scientific study of artificial lighting for industrial and for other purposes appears to be in the forefront of modern progress, to the inestimable benefit of all classes of the community. If any justification were needed for giving the utmost prominence to this subject, it would be found in the following statement: That unsatisfactory illumination results in (1) An increase in the number of accidents to persons using the premises concerned; (2) possible damage to eyesight and to health; (3) diminished output of work; (4) imperfect discipline.

The terms "lighting" and "illumination" are generally rather mixed in their application, in fact, the former is commonly used where the latter is really intended. Illumination is, of course, a measurable quantity, and is taken as the intensity of the light falling upon a given surface.

Systems of Lighting.—Of the many systems of electric lighting, the ones at present claiming our attention most are: Arc lamps and incandescent lamps, the latter being subdivided into the carbon and the metal filament types, this last comprising the ordinary vacuum lamp of a reputed efficiency of about 1·2 watts per candle-power, as well as its very modern successor, the "half-watt" or gas-filled lamp. Each have their proper sphere of application, which it is the duty of the engineer to decide, and, without a careful enquiry into and a study of all the conditions peculiar to each case by him, waste and inefficiency inevitably result. Lighting no longer consists in merely hanging up lamps, but rather in a proper study of all the conditions obtaining, such as area, height, nature of work carried on, reflecting surfaces, system of current supply, &c. Proper switch control and a suitable system of wiring also enter more or less directly into the ultimate efficiency of the installation as a whole.

As each new type of lamp is put upon the market, the average layman, whether he be a factory owner or not, is quite apt to suppose that the new-comer will shortly oust all its predecessors and become in undisputed possession of the field of artificial lighting. The untiring activities of the modern salesman, together with the enormous extension of technical advertising, are, no doubt, largely responsible for this. The new gas-filled electric lamp has not yet however ousted its parent, the ordinary vacuum type-metal filament. Arc lamps are still made and sold, and our old friend the carbon filament is with us still.

Overall efficiency or watts consumed per candle-power given out is usually the main if not the only point considered in the selection of lamps. This should not be; it should rather be the total cost per candle-power hour, which, of course, takes into account the first cost of the lamp and its life, as well as the cost of current. In a case within the author's experience it paid to use the old-fashioned carbon filament lamp with its wasteful consumption of 3½ watts per candle-power. This occurred in a factory where not only were more lamps lost by breakage than by ordinary burning out, but the current was supplied by steam-driven generators, the boilers for which were fed entirely on refuse which would otherwise have cost money to cart away.

The Lay-out of Lighting Schemes.—The tendency of the present day, in arranging schemes of artificial lighting, is, to endeavour to crystallise the whole matter as much as possible, and in the case of lighting into three points, that is, height of lamp or lighting "unit," spacing distance, and the candle-power of the unit employed. Whilst useful enough and easy of application in *new* buildings, where the architect is willing to give consideration to the requirements of artificial lighting, in *old* buildings the points mentioned commonly have to be the subject of part consideration only, in order that other influencing conditions may have necessary consideration. Hard and fast rules for the lay-out of artificial lighting in an industrial type of building would therefore appear to the author as undesirable, even if possible of general application. It is true that progress is being made in the direction of deciding as to what is a suitable standard or intensity of illumination for various processes and kinds of work, but this is and will probably remain, as the *minimum* illumination necessary, rather than the average. Lay-out must, therefore, be settled not on this point only, but on due consideration of the many other variable points which will be found to enter into almost every case one meets in practice.

A point one would specially draw attention to in this connection is the need of "general" as well as "local" or "individual" lighting in most, if not all, of the premises which the mechanical and the civil engineer have to deal with. Individual or local lighting of sufficient intensity for machine tools, benches, desks, &c., is necessary if each operator is to properly perform his duties. "General" lighting, on the other hand, is equally necessary, for by this proper supervision and discipline is possible and the safety of those persons secured who have to move about through passages and gangways. This need of "general" lighting is, even at the present time, often entirely overlooked.

The "general" lighting should be so arranged that a fairly uniform illumination is produced, say, with an allowable variation between maximum and minimum of 20 to 25 per cent., and where individual lighting is additionally provided the value of the former is considered sufficient if of the nature of about 1·5 foot candles. Compared with the recommendations of the Home Office Committee such a figure will seem luxurious, the recommendations referred to being: (1) ·25 of a foot candle over "working areas" of workrooms (without prejudice to the illumination required for the work itself), and (2) ·1 of a foot candle in all parts of factories and workshops not included under (1) and where persons are liable to pass.

Standards of Illumination.—The figures quoted by various authorities show considerable variation in idea as to what is considered necessary, as the following extracts will show:—

In a drawing-office... ...	(*a*)	6 to 10 foot candles.
" " "	(*b*)	7 " "
" " "	(*c*)	8 " "
In a warehouse or stockroom	(*a*)	·5 " "
" " " "	(*b*)	1·5 to 2 " "
In a foundry	(*a*)	3 to 4 " "
" "	(*b*)	·4 of a foot candle (minimum).
In offices	(*a*)	4 foot candles.
" "	(*b*)	3 " "

The author would suggest that the adequate standard of illumination is such as will allow the process to be carried on or the work to be done without eyestrain or special effort on the part of the operator. In this matter personal prejudice often counts most, where the layman is the only authority concerned—many persons from sheer want of observation having no idea as to what is adequate illumination. As an illustration of this statement, it may be cited that the author on one occasion was asked to reduce the lighting costs in a certain building. A large joinery shop had been fitted with 16 c.p. lamps throughout, the foreman having insisted that these were absolutely necessary. One evening, after business hours, and in the foreman's absence, every lamp was changed to 8 c.p. The foreman never noticed it, and no complaints were heard.

In the near future probably the greatest importance of a standard of illumination in places coming under the Factory and Workshop Acts will consist in a Government standard of a *minimum* illumination everywhere. It is to be hoped that when our great country returns once more to the arts of peace that legislation of this character will be enacted, as well as other regulations incidental thereto, which will result in intelligent methods of artificial lighting, profitable to the owner and beneficial to the workman. Such an event would bring into greater prominence the measurement of illumination, which, until recent years, had been practically left untouched. By measurements taken at regular intervals of time, any deterioration is detected and the cause of it removed. Deterioration may readily be so gradual as to pass unnoticed,

* Paper read before the Junior Institution of Engineers, October 18th, 1916.

but its results will inevitably occur; that is, imperfect quality or decreased output of work. The modern "illumination" photometer is an instrument which is simple, reliable, cheap in first cost, and well worthy of more extended use.

The Essentials of Satisfactory Illumination.—These may be summed up as comprising: (1) Adequacy, that is to say, the *degree* of illumination produced on the working surface must be sufficient for the work or operation to be properly carried on. On the other hand, over-illumination is quite possible, and its effects are naturally harmful. (2) The lighting unit or source of light must be so placed that the light does not strike directly upon the eye of the operator either when he is engaged on his work or when looking horizontally across the workshop or room. This recommendation of the Home Office Committee may be summed up in the words: "Light on the object and not in the eye." Thus "glare," whether produced directly or indirectly, should be avoided. (3) The lighting units should be so placed as to prevent shadows on the work or heavy shadows about those parts of the premises to which the workpeople have access. This does not suggest that an absolutely uniform degree of illumination everywhere is necessary. The opposite is desirable as affording relief by contrast. (4) Constancy, so far as the degree of illumination is concerned, is also necessary. Where the current is supplied from public lighting systems, there is usually little or nothing to complain of in this direction, but where the lighting receives its current from a private plant on the premises, constancy of illumination is by no means always prevalent.

In one very notable instance within the author's recent experience, the lamps in the most important part of the works, by their combined efforts, give any illumination from zero to maximum, and when the latter standard prevails it is just possible to see the requisite detail of constructional parts by the added brilliancy of a candle.

Reflection and Colour.—The value of these two factors in artificial illumination is commonly overlooked. As regards the value of "general" reflection, that is to say, from the walls and ceiling, the Factory and Workshop Act has, by its insistence as to regular limewashing, done much to provide a cheap and effective reflecting surface of the highest order. The experiments carried out at the National Physical Laboratory by the Home Office Departmental Committee, in a room specially fitted out with different methods of lighting, may here be cited. Three systems of lighting were tried: Direct, indirect, and shielded. With the walls blackened instead of whitened, the reduction in illumination at the centre of the room was approximately 25 per cent. for direct lighting, 7 per cent. for indirect lighting, and negligible for shielded lighting. The influence of colour in artificial lighting is often overlooked. Lighting of a colour that will enable a person to not only do his work but remain at it for hours at a stretch without feelings of fatigue or depression, is obviously desirable.

We are naturally inclined to light of a reddish tint or at least light of a colour associated with that end of the spectrum. The present lighting restrictions have in many cases appreciably altered the colour of both natural and artificial lighting, glass roofs and side windows being painted a deep blue. The effect of mental depression on remaining under bluish light for any length of time in some persons is most noticeable. Mercury vapour lamps, when used for general lighting, have been noticed to give different results with different people, where all other conditions were equal; one man, for example, insisting on the addition of an ordinary glow-lamp in order to carry on his work, whereas other workers considered this quite unnecessary.

Direct or Indirect Lighting.—As to which of these two systems should be chosen for factory lighting is a question which has been the subject of some considerable argument during the last few years. The use of metal filament lamps of high efficiency, candle-power, and intrinsic brilliancy has undoubtedly made indirect lighting possible where it would be otherwise quite unthinkable. The results of the Home Office Committee's tests in connection with this matter, and which have already been briefly referred to, would suggest that with indirect lighting the illumination was required to be greater than with direct lighting. Even where a comparatively uniform degree of illumination everywhere is required, this can be obtained by modern types of reflector whose characteristics are known to start with, combined with careful spacing of the lighting units.

Reflectors and Fittings. Obviously for either "direct" or "indirect" lighting the most important item is the reflector, or, as it is more often called, the "shade." Until recent years, for incandescent lighting, nothing else scarcely was used but the shallow, conical enamelled iron or opal glass reflector. Custom clung very tenaciously to this, probably on account of cheapness. For years, imported from "another" country, the best one could say of this type of shade was that it was badly made. As a shade, it shaded very little else than the ceiling. In combination with a carbon filament lamp it was bad enough, but with a metal filament lamp, with its higher intrinsic brilliancy and extended length of bulb, the evil effects of an unscreened light became infinitely worse. Happily, with the war, a limit was put on the supply of these goods, with the result that properly-designed reflectors in glass or steel are more open to appreciation in spite of higher first cost. One refers particularly to the prismatic glass reflectors of the "Holophane" type and also to the pressed steel reflectors of the "Benjamin" pattern, intended more particularly for factory service. By the choice of a reflector either of the "extensive," "intensive," or "focussing" type, and with the spacing distance arranged with regard to height, it is easily possible to obtain any desired illumination, and with the source of light well screened from the eye.

With the use of tungsten lamps ventilation of the reflector or lamp fitting becomes necessary, owing to the high temperature of the filament, if the lamp is to last any length of time, and with half-watt units the need in this direction becomes very greatly increased.

The details of fittings, apart from reflectors and shades, still leave room for improvement. Lampholders in particular might well be more substantially made, and with more area of contact in the electrical parts, ensuring cooler running with lamps of high candle-power.

Flexible cords for pendant fittings are frequently either poor in quality or deficient in section, or both, and frequently a good cord is used in an unsuitable position. When viewing modern installations in factory premises, one often wonders if proper *factory* types of flexible cord have yet come under the purview of installing contractors.

Maintenance and Upkeep.—Proper systematic maintenance of electric-lighting installations is a matter which, in this country, has received but the scantiest of attention. It is no uncommon thing for a factory, or other building, to spend a large sum of money in a lighting equipment which, once started, is left to take care of itself indefinitely, with the exception of spasmodic attempts at lamp renewals, and this only when the lamps become either burnt out, broken, or stolen. The cleaning of lamps and reflectors is never thought of. If considered properly, the lighting is virtually a tool, one of the tools necessary to the work going on, and this work cannot be as properly and economically done if this tool is to be allowed to fall into utter deterioration. The cost of lighting commonly bears but a very small proportion indeed to the total stand-by, or "dead-rent" charges of the establishment, and this cost could only be increased by an inappreciable amount when the cost of systematic maintenance is added. In this country there are comparatively few electrical firms engaging in maintenance work, and their charges are somewhat diverse, being apparently based more upon speculative guesswork than the results of experience. Recently, the author had occasion to send out enquiries for maintenance to several firms, specifying carefully all necessary detail. The following summarised figures illustrate the divergence referred to:—

Type of Building.	Maintenance Costs.		
	Firm "A."	Firm "B."	Firm "C."
Commercial	6·4	2·4	2·0
Manufacturing (*a*)..	5·2	3·07	4·0
,, (*b*)..	4·5	2·8	4·0

The maintenance costs are expressed in shillings per point per annum, and include renewals of lamps, fuses, switches, &c., and cleaning of all shades and reflectors and lamps

monthly, with the exception of firm "B," who did not include for switch renewals. Maintenance contracts, when carried out by general electrical contractors, should, in the author's opinion, include a half-yearly test and report upon the insulation resistance of the job; a point by point test of the earthing of all metal work; checking of the supply company's meter readings and quarterly charges; and might also, in many instances, justly provide for a guaranteed minimum illumination in foot candles to be maintained in specified areas or places. In large establishments it would doubtless pay well for the engineer-in-charge, or his staff, to carry out the maintenance duties themselves, the owners, of course, ordering up material required for renewals as requisitioned by them. The necessity of proper maintenance has been emphasized by a well-known writer on factory lighting, Mr. C. E. Clewell, who points out that in extreme cases the loss of light produced by dirt on lamps and reflectors may amount to as much as 50 per cent. From a test which this writer has published concerning a factory installation, the deterioration in lighting due to dust and dirt over a period of 48 days was as follows: Starting from an initial illumination of 4 foot candles at the end of six days this had become 2·8; at 18 days, 2·2; at 36 days, 2·1; and at 48 days, 2. Glass reflectors were used.

The workers themselves, who under ordinary circumstances pay little or no attention to the quality of the illumination, did, I noticed in a certain department of a factory, suddenly acquire a most absorbing interest in it—the reason being that they had been changed over from time-work to piece-work. Under the new conditions, mysterious and invisible acts of transference of new clean lamps into this particular department soon developed into a fine art. Proper maintenance had become established—unasked and unpaid for.

Supply of Current.—The opportunity is sometimes presented of choosing between a direct-current supply and an alternating current. So far as the ordinary working voltages are concerned, there is little to choose between them, if metal filament lamps, either of the vacuum or the gas-filled type, are used. If small candle-power lamps of the half-watt type are essential, and alternating current is available, a static transformer may be used to convert down from a higher voltage to, say, 50 volts when lamps of the 30 and 60-watt sizes become available for parallel operation, but such cases require careful consideration if the runs of the wiring are of considerable length, as the voltage drop may necessitate unusually heavy conductors. For arc lighting one generally prefers a direct-current supply.

With low periodicities fluctuations in light are well known in alternating-current arc circuits. It has been stated that at 25 cycles the variations in brightness in incandescent lamps are quite perceptible to the eye. Naturally, the effect becomes more decided if metal lamps of low candle-power, having thin filaments, are employed, these readily receiving or giving up their heat.

Private Plant or Public Supply.—As to whether the supply of current in the case of a large industrial establishment should be taken from a private plant on the consumer's premises or from the public supply, when each course is open to consideration, is a question which has long since been the subject of controversy. The central station man is, or should be, a salesman, and is entitled to use all legitimate means of pushing business. Such items as, the first cost of a generating plant, interest and depreciation thereon, and the need of skilled labour to look after it, can readily be used as a means of suggesting to the lay mind that to take the supply off the town mains is the only economical thing to do. This does not necessarily follow, however, and essentially so in the case of establishments where a power plant is put down. The additional cost of making provision in the power plant for supplying the lighting current is commonly such as to render it well worth doing on economical grounds, whether the plant be for the distribution of the power mechanically or electrically. With a supply from his own plant, the owner has not to watch possible variations in the annual cost of current due to such causes as minimum or maximum demand, total units consumed, &c., nor to enter into any agreement for a number of years in order to get down to what may appear to be a favourable rate for supply. The whole question must be thought out in an unbiased way, due regard being paid to all the conditions affecting the particular case under consideration.

In settling upon a supply from the public service, the factory owner is frequently well in need of independent advice as to agreements for charging, if the most economical arrangement is to be arrived at. When a typical agreement is put forward for consideration, before the prospective consumer can be advised as to taking up same, one needs to weigh very carefully the several conditions which are commonly sought to be imposed. Such, for instance, as the requirements that all the consumer's lighting must be taken from the one source of public supply only, and this for a period of, say, three, five, or more years. Further than this, the rate of supply and system of charging are both fixed for the whole period, regardless of possibilities which might prove advantageous if they were open to be adopted. Supply authorities frequently offer alternative methods of charging, usually a flat rate, and a maximum demand system is one of its several forms. With a combined power and lighting load it is not unusual for a consumer to be allowed to have a certain proportion of the total units consumed (say, 10 to 15 per cent.) to be allocated to lighting, any proportion above this being charged at a somewhat higher rate. In factories where the load is mainly power, this works out very satisfactorily for the consumer, and likewise, no doubt, to the supply authority.

Switch Control of Lighting.—Proper switch control of lighting is a matter well worthy of more careful consideration than it usually receives, and this would result in added convenience and economy. The points one has in mind are: (*a*) A more liberal use of switches; (*b*) better location; and (*c*) the use of two or three-point control.

(*a*) The best of lamp switches are not expensive to buy, and by providing an ample number, in proportion to the lamps installed, every facility is given for exercising economy.

(*b*) For individual or local lighting, the switches should be as conveniently near as possible to the lamps controlled. These can be further controlled by a master-switch or switches placed conveniently for use by the shop foreman, who would also control the "general lighting."

(*c*) In some cases it is a great convenience to be able to control one or more lights from two or more positions, by what is commonly known as 2-way and also "intermediate" switching. Lamps switched near doorways are an example. Economy commonly follows the convenience.

Switches in factories commonly suffer from lack of adequate mechanical protection. Where conduit wiring is adopted, iron switch boxes which absolutely protect the switch and only leave the knob projecting are to be preferred. Owing to its light construction, the ordinary "5-ampere" switch, even if only loaded to less than half this amount, is at modern voltages, liable to rapid wear. The author has often found it pay well to adopt switches rated as 10 amperes for 2 or 3-ampere circuits on this account.

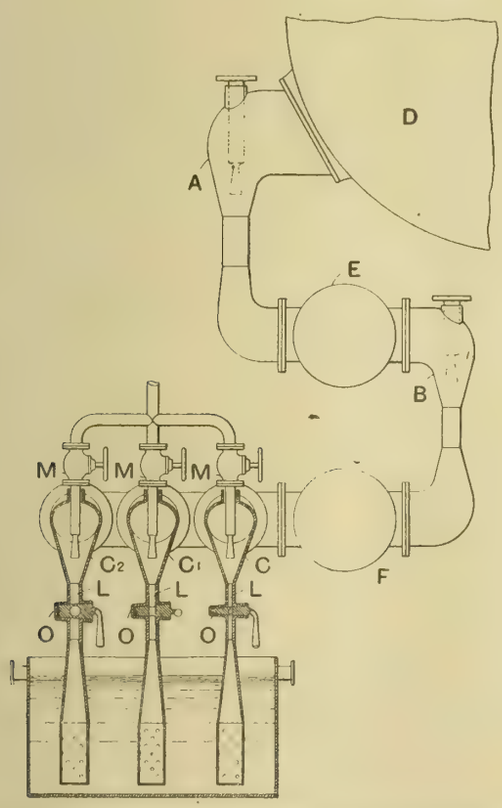
Systems of Wiring.—For factory use, screwed tube is very largely used, as affording a good mechanical job, as well as a sound one electrically. From a fire risk point of view, it is obviously beyond question. It should preferably be kept clear of all other metal work, be made electrically and mechanically continuous throughout, and properly earthed at least at one point. Inattention to earthing of metal work on the one hand, and to the careful insulation of the wiring and electrical conductors generally on the other, may often lead to very unexpected faults in the lighting, to say nothing of the risk of personal shock or fire. In these days, when cheapness in first cost counts for so much, there are naturally several competing systems, each meeting with more or less success, according to the positions chosen for their use. When placed well out of reach, and in dry situations, open cleat wiring may often be used very successfully to form a cheap job.

With a view to maintaining efficiency in the lighting, attention may well be given to the following details in the circuit wiring: (1) "General" lighting to be circuited separately from the local lighting, and, where possible, alternate units to form a circuit; (2) a more liberal allowance in the number of circuits or "ways" per distribution board should be adopted, thus insuring a minimum of the lighting units being out of

action in the event of a circuit fuse blowing; (3) motor circuits to be entirely distinct from those supplying lighting, both as regards wiring and the fusing at main or sub main distributing boards.

APPARATUS FOR DISCHARGING AERATED VAPOUR FROM STEAM CONDENSERS.

An arrangement to discharge, by means of steam operated ejectors and with an economical expenditure of steam, varying quantities of air contained in aerated vapour which has been withdrawn from a steam condenser under vacuum by one or more steam jets, has recently been designed and patented by Mr. D. B. Morison, of Hartlepool Engine Works, Hartlepool. Referring to the illustration it comprises multiple final ejectors C, C_1, C_2 arranged in parallel with each other and in series with the ejectors A and B, E and F being intermediate condensing receivers. The passages from the ejectors, namely, the combining tubes L, are provided with cocks O, and the steam supply to the ejectors is provided with valves M, so that one or more of the ejectors may be brought into use when desired. The ejectors may each have any suitable



APPARATUS FOR DISCHARGING AERATED VAPOUR FROM STEAM CONDENSERS.

air capacity, and in the arrangement illustrated they are designed for capacities for discharging respectively 1lb., 2lbs., and 4lbs. of air, contained in the aerated vapour withdrawn from the condenser D, per unit of time, and may be operated in the following manner:—

Ejectors in Operation.	Capacity of each Ejector.	Total Capacity.
A	1	1
B	2	2
A+B	1+2	3
C	4	4
A+C	1+4	5
B+C	2+4	6
A+B+C	1+2+4	7

By these means of selection or combination the capacity of the final discharging apparatus can be increased by such increments as will enable stability to be maintained throughout a large range of air quantities, and the air can be discharged with a highly economical expenditure of steam.

USE OF TITANIUM IN STEEL CASTINGS.*

BY W. A. JANSSEN.

Notwithstanding all that has been said concerning the harmful effects of phosphorus and sulphur in steel, the occluded oxides and gases, such as iron oxide, Fe_2O_3, and an undefinable oxide, probably FeO, free oxygen, nitrogen, and occluded slags, are the real causes of many of the troubles of the steelmaker. It is with the occurrence of these elements and their elimination that he is especially concerned. It has been definitely demonstrated that the presence of oxygen, and possibly nitrogen, in steel reduces its static strength, dynamic properties, and abrasive values, and increases its tendency to corrode. To-day the presence of oxygen and oxides in steel is considered more harmful than even relatively large amounts of phosphorus and of sulphur. In a measure the same is true of nitrogen, although the investigations in this direction have not been sufficiently complete and the results are variable and uncertain. Advanced methods of analysis allow the isolation and determination of both of these gaseous constituents. Unfortunately insufficient credence has been given to their existence.

Many analyses of steels will disclose an oxygen content of approximately 0·05 per cent. This may be compared with the analysis of other undesirable constituents, such as phosphorus and sulphur. It must, however, be borne in mind that it is not the nascent oxygen itself which causes the harm, but rather the compounds which it so readily forms. The presence of 0·05 per cent. oxygen may mean, if it is combined with the iron, the existence of 0·22 per cent. of oxide of iron, an amount sufficient to materially affect the quality of the metal. Bessemer or converter steels contain the largest amount of occluded oxides, with the open-hearth steels next (the steel made by the basic process contains more than that made by the acid process), crucible steels next, and electric steels last. The steels made in the electric furnace are practically free from oxides. It will be seen that the accepted range of the quality of steels, from the oxidising bessemer process to that of the electric furnace, is determined by the freedom from occluded oxides. In spite of theories to the contrary, notwithstanding, it is an established fact that the presence of oxides in steel materially accelerates corrosion. All impurities in steel are electro-negative as compared with iron except the oxide of iron, which is electro-positive. The difference in potential set up between this couple in the presence of moisture or dilute acids causes the steel in the proximity of the oxide areas to corrode rapidly.

The reason for the occurrence of cracks in steel castings is an oft-debated question. Aside from cases where no consideration has been given to the proper distribution of metal in the design of the casting, unduly restricting the cooling and shrinkage, the cause for cracks has been considered to be due to red-shortness. These defects usually are found where the metal, in cooling from its liquid through its plastic or viscous state, due to its lack of stability, cracks under pressure or restricted shrinkage. Sulphur, to which is usually attributed the cause of red-shortness, is generally given credit as being the cause of the cracks. Even when the casting has been designed properly and made with a sulphur content of not over 0·025 per cent., these same cracks appear periodically. An examination of these cracks, even with this abnormally low sulphur content, discloses a crystalline fracture. It has been observed that when the furnace is again brought to a normal condition of operation and the amount of occluded oxides reduced, these cracks again disappear. It is known that this occluded oxide of iron also has the property of causing red-shortness. Furthermore, it has been observed that in an over-oxidised metal, in the range of the plastic state of cooling, the liability of the occurrence of cracks is greatly increased.

That these cracks occur in castings which are uniformly sound and free from blow-holes throughout, seems to indicate that the normal addition of the deoxidisers, ferro-silicon and ferro-manganese, which are governed by specifications, do not entirely free the metal of its oxides. The introduction of

* Paper read before the Cleveland meeting of the American Foundrymen's Association, September, 1916.

these oxides into the metal is primarily dependent upon furnace manipulation. In the bessemer process it may be due to over blowing, in the open-hearth process to the use of too sharp a flame, the admission of too much air for combustion, or the use of too much ore in refining. Even in the electric furnace, which is supposed to refine steel in a neutral atmosphere, oxides find their way into the metal due to the inability to maintain the calcium-carbide slag, which is the primary function of an electric furnace in the production of deoxidised steel. With present-day furnace operation, which at best is variable and manipulated by rule-of-thumb, the steelmaker must have at his command a positive deoxidiser or cleanser to augment the ordinary deoxidisers such as ferro-silicon and ferro-manganese.

With the discovery of ferro-alloys of silicon and manganese containing high percentages of the active elements came the hope of an assured uniform quality of steel. As deoxidisers, modern ferro-alloys are efficient in a measure, but have certain limitations. It is the function of these deoxidisers to combine with the occluded oxides; the resulting products rise and become a part of the slag. Unfortunately the temperature of the metal and its resultant fluidity do not always permit these deoxidisers to complete their cycle and rise to the slag; they are entrapped as inclusions and the occluded gases are not entirely deoxidised. The known presence of oxides in excess of the amount which can be deoxidised by the usual additions of ferro-silicon and ferro-manganese is not permitted because of specification tolerances for manganese and silicon content.

Silicon, comparatively speaking, is not a strong deoxidiser, and when it is added to steel a portion of it remains in the steel either as an alloyed constituent, or the products of its oxidation may remain as inclusions. The usual analyses for silicon do not disclose whether or not the silicon is present in the steel as an alloyed silicide, as silica, or as the silicate. Even if the silicon manifest itself as a silicide, showing a high silicide percentage, a wild heat is apt to result, requiring the use of a further deoxidiser (aluminium) when pouring the moulds. In conjunction with manganese, double silicates of iron and manganese frequently are formed. Such a constituent may contribute to excessive segregation, although singularly a dirty steel often discloses very little segregation.

The oxide of manganese formed with the use of ferro-manganese as a deoxidiser, although of low specific gravity, may not rise and become a part of the slag, instead it becomes entrapped and reacts with the carbon of the steel to form carbon monoxide. The chemical formula is as follows:

$$MnO + C = Mn + CO$$

Chemical analyses do not disclose in what combination manganese is present in the steel, whether as a sulphide, carbide, or oxide. If present as a sulphide or carbide, it may manifest itself as a segregated area of weakness. If present as the oxide of manganese, it exists in its most deleterious form. The existence of oblong surface blow-holes may be said to be due directly to the presence of manganese oxide, indicating the fact that the metal has not been thoroughly deoxidised. As previously stated, the manganese oxide reacts with the carbon of the steel to form carbon monoxide, which, by expansion, will be forced to the surface of the casting, resulting in the formation of oblong blow-holes. This same type of blow-hole may exist due to the reaction of the carbon of the steel with the iron oxide. Blow-holes may also exist in other parts of the casting. Usually they are either spherical or lenticular in shape, and generally they are due to imperfect moulding, imperfect venting, damp sand, or the entrapping of air or aqueous vapour formed by the hot steel.

The actual effect of nitrogen in steel is still a mooted question. It is only comparatively recently that any research has been done on this subject, the most of which has been performed by European metallurgists. In a measure their findings have been incomplete and their results somewhat variable. This may be due to a variance in the methods of analysis. Some investigators, even after synthetic incorporation of nitrogen, on analysis find less nitrogen present than others find in the usual product of the furnaces. By some it is held that the effect of nitrogen in steel is much the same as phosphorus, in that it causes cold-shortness and brittleness. Analysis of steel for nitrogen seems to indicate that the greatest amount is found in bessemer steel, with smaller amounts in the open-hearth product and still less in steel made in crucibles and electric furnaces. The amount present in the latter processes is dependent on the nitrogen content in the stock charged. If the presence of nitrogen be determined and if it is considered undesirable, its elimination or reduction can only be effected by titanium to form stable titanium-nitride; ferro-silicon, ferro-manganese, and even vanadium having no affinity for nitrogen.

To augment the deoxidising effect of ferro-silicon and ferro-manganese, steelmakers have resorted to the extensive use of aluminium. Aluminium is the most powerful deoxidiser known. Nevertheless its use in quantity is a menace in that the resultant product of oxidation—alumina—is a viscous oxide which has a melting point at 2,010° C. This material is infusible at the temperature of the molten steel and also renders other slags infusible. Because of its physical characteristics, the alumina, as formed frequently, does not find its way to the slag, but remains entrapped in the steel as shot or streak inclusions.

Titanium, until a comparatively few years ago looked upon as one of the rare metals, undoubtedly is one of the most powerful deoxidisers and denitrogenisers known. Titanium as an element is a hard, brittle material having a greyish silver lustre. It has a melting point of about 2,300° C. Titanium burns energetically in oxygen and is the only known element which "burns" in nitrogen. It is widely distributed in nature, usually as a dioxide in rutile, brookite, anatase, and in some clays and as ferrous-titanate in titaniferrous iron ores. The knowledge of its effects has long been classic. The use of titanium, however, was prohibitive because of its high cost. Titanium at the present time may be obtained as one of the ferro-alloys.

The ferro-alloys of titanium, in general, are produced by two distinct processes, by the electric furnace process as developed by Auguste F. Rossi, and by Dr. Hans Goldschmidt by his well-known aluminothermic process. Each of these alloys has its own particular application, the function of both, however, being the same. The ferro-alloy made by the Rossi process consists essentially of microscopic particles of titanium carbide held in a matrix of grey iron. Its analysis is as follows: Titanium, 15·79 per cent.; carbon, 7·46 per cent.; silicon, 1·41 per cent.; manganese, 0·11 per cent.; phosphorus, 0·05 per cent.; sulphur, 0·08 per cent.; iron, by difference, 74·30 per cent. The analysis of the alloy made by the Goldschmidt-thermit process is as follows: Titanium, 20·22 per cent.; manganese, 0·50 per cent.; carbon, less than 0·10 per cent.; aluminium, 5 to 8 per cent.; phosphorus, 0·10 per cent.; silicon, 0·75 per cent.; sulphur, 0·02 per cent.; iron, by difference, 70·31 to 73·31 per cent. The product made by the thermit process, it will be noted, is peculiar because of its aluminium content and freedom from carbon.

The chief value and merit of titanium lies in its positive action in the removal of the occluded oxides, nitrogen, and entrapped slags, due to the fusibility of titanic oxide as formed and its greater stability as compared with iron oxide. Its function is further augmented by the increased fluidity due to the increased temperature because of the exothermic reaction, thereby permitting freer movements of the oxidised products to slag. It has been found that the present-day method of using ferro-titanium is to augment the incompleted cycle with ferro-titanium after the other deoxidisers have been added. These may be added in the ladle, or in the furnace before tapping. After the titanium has been added, it is imperative and essential that the ladle be held from five to ten minutes before pouring in order to allow time for the completion of the reactions. No fear need be had of the chilling of the metal, inasmuch as the temperature is raised appreciably, due to the exothermic reaction. It is essential that the titanium be not added until after the additions of ferro-silicon and ferro-manganese have been made. On account of the greater affinity of titanium for oxygen, the ferro-silicon and ferro-manganese must be given an opportunity to complete their primary deoxidation, thereby eliminating selective oxidation. It is also essential that the ferro-titanium be added as soon thereafter as possible so that the alloy does not become a part of the slag and there perform its deoxidation. Ferro-titanium has its application as a deoxidiser and cleanser in the crucible, converter, open-hearth, and electric furnace processes of steel manufacture, as well as in the cast iron and malleable iron industries. If ferro-titanium

be used in the crucible process, it may be added as a part of the charge, being placed well down toward the bottom of the pot, or added after the manganese addition has been made. Because of its intensified affinity for occluded gases and cleansing action on inclusions, its use extends to the metallurgical processes for the more common non-ferrous alloys and to rare metals.

Titanium in combining with oxygen to form titanium-oxide with a heat formation of 215,000 calories, acts as a flux for silicates and other slags, which normally would remain in the slag, rendering them sufficiently fluid to rise through the metal and pass into the slag. Titanium, when at about 800 C., combines with nitrogen to form the stable titanium-nitride which usually finds its way to the slag. Microscopic examination, however, sometimes reveals the existence of occluded tiny, hard, pink crystals of titanium-nitride, which, however, are less harmful in effect than the occluded nitrogen. With all these beneficent effects, its use beyond a certain amount is of no avail and in a measure harmful.

Titanium, singularly, does not form alloy steels as do the other deoxidisers, such as silicon, manganese, and vanadium. Many analyses of titanium treated steels do not reveal a titanium content higher than 0·025 per cent. With the use of alloys containing more than 10 to 15 per cent. titanium, the results are not as effective owing to the slower rate of solution. Much has been said and written about the relative efficiencies of ferro-carbon-titanium and the carbon free alloys, with particular reference to their comparative solubilities because of the carbide content. The carbon in the ferro-carbon-alloy in excess of that present as titanium-carbide is present almost entirely as graphitic carbon, which in all probability does not affect the rate of solution. If there be an effect, in all probability it is offset by the lower rate of solution of the alloy of higher titanium content. The carbon free alloy has a special application to the lower carbon steels of definite carbon content which might be increased by the use of the carbon alloy. Its use, however, involves the presence of aluminium with possible Al_2O_3 contamination.

The amount of ferro-titanium used depends in a measure on the kind of steel to be treated. In rail steel an addition of 13lbs. of the 15 per cent. alloy per net ton, representing a metallic titanium addition of 0·10 per cent., is satisfactory. In the use of titanium for steel castings the addition of 1½lbs. to 2lbs. per ton of metal charged, in adition to the usual ferro-silicon and ferro-manganese additions, is usually sufficient to deoxidise the steel. The amount of ferro-titanium added, however, should be dependent on the quantity of impurities which are to be removed and the process of manufacture.

Some claims have been made for the use of titanium in excess of the amounts necessary for deoxidation in the elimination of sulphur and phosphorus, or at least to convert them into compounds having less harmful effect. It has been stated that the sulphur is eliminated as a sulphide or as a sulpho-cyanide of titanium and that the phosphorus passes to the slag as titanium-phosphate. These claims in their entirety, however, have not been substantiated.

In the low carbon or soft steels the presence of blow-holes, occluded gases, and slag inclusions is greatly aggravated due to the metal being longer subjected to the oxidising action of the flame or blast, or because of its being necessary to increase the temperature of the metal for successful and economic teeming. Soft steels, because of this low carbon content, cool more rapidly after having reached a point of initial solidification, thereby the occluded gases are not afforded sufficient time to escape before the metal has reached its plastic state. Titanium, properly apportioned in conjunction with proper treatment, will cleanse and purify the metal. With the use of titanium in the higher carbon steels, it has been found that these steels are softer and less brittle than steels of the same carbon in which titanium has not been employed, due in all probability to the more uniform distribution of the ferrite network.

In alloy steels, where special alloys such as nickel, chromium, and manganese are added because of a special function, the quality and properties of the metal are improved by the further adition of titanium for the elimination of the oxides of nickel and chromium, both of which contribute to the brittleness of steel. The manufacture of manganese steel is greatly benefited by the proper addition of titanium. With the use of this alloy, the manganese is disseminated uniformly, resulting, with proper heat treatment, in a tough, homogeneous product.

During the past few years specifications for steel castings for specific designs and service have demanded the use of vanadium. Although the presence of vanadium in steel undoubtedly has improved its physical properties, it is questionable whether vanadium manifests its maximum efficiency in plain carbon steels, especially within the carbon range of steel castings. The vanadium addition is calculated as an alloying constituent, the amount present in the final product being within three or four points of the desired calculated content. Vanadium has manifested its greatest value when used in conjunction with chromium and nickel as a deoxidiser. Vanadium is only 70 per cent. as efficient as titanium, and has but little effect upon nitrogen.

It will be seen that with proper proportioning of the alloy and proper manipulation of the heat, steel is improved in density, strength, toughness, and durability when titanium is used. This improved quality of product is not due to any direct or alloying effect of titanium, but rather to its value as a deoxidiser and cleanser in removing harmful occluded gases and slags. It must not, however, be looked upon as a cure-all to rectify the evils of poor stock selection and bad furnace practice, but rather to make good steel better by further augmenting the incomplete reactions of the best present-day deoxidisers and clarifiers now in use. With the elimination of the occluded oxides and slags, steel, because of its increased density and homogeneity, has improved static and dynamic properties. A comparative test of 20 untreated and treated heats showed an increase in the ultimate strength of approximately 15 per cent. with no reduction in elasticity and contraction. A remarkable endurance test was conducted by Enrique Touceda on untreated and titanium treated steels of practically the same chemical composition. The test was conducted in a Wright-Souther machine at a fibre stress of 38,872lbs. The untreated steel withstood 2,676,000 revs. at this pressure, whereas the titanium-treated steel withstood 18,274,900 revs. at pressures varying from 38,872lbs. up to 45,939lbs. fibre stress.

Many tests made on rails and machine parts indicate the ability of titanium-treated rails to withstand shocks and abrasion, the life of gears and rails being about 50 per cent. greater than those made of untreated steels. In a comparative test on gears it was found that titanium-treated gears, although made of 0·20 per cent. carbon steel too soft to be ordinarily considered acceptable for machine parts, outlasted untreated steel gears of the same composition three to one.

Steel, instead of being a homogeneous chemical compound, must be considered as a heterogeneous mechanical aggregate of crystals of definite shapes, welded on to the adjacent crystals. The efficacy of these welds and the ultimate strength of steel against fracture, rupture, and fatigue is directly dependent upon the absence of segregated impurities which segregate at the boundaries of these crystals. With the elimination of these occluded impurities by the use of titanium these crystals are brought into a closer weld with one another. Segregation is further reduced by the elimination of the occluded oxides, which, because of lower specific gravity, rise and form a path for the selective segregation of phosphorus, sulphur, and the crystals of higher carbon constituency.

With the present high cost of ferro-manganese and the attendant shortage of supply, the writer has carried on some extensive experiments to conserve his ferro-manganese without affecting the quality of the product. Realising that the manganese present in steel castings contributes only indirectly in increasing the strength, the purpose of these experiments was to reduce the manganese from 0·75 to 0·50 per cent. To be assured of the same strength, the usual ferro-manganese addition was reduced from 320lbs. for a 20-ton heat to 200lbs. and the ferro-titanium addition increased from 60lbs. to 120lbs. Tensile tests for these heats showed an average ultimate strength of 68,000lbs., for an 0·20 per cent. carbon steel, with an average elongation of 30 per cent. and a reduction of area of 47 per cent.

It can be well appreciated that the use of ferro-titanium in making steel castings is no longer an innovation, but rather a necessity to offset the vagaries and shortcomings of present-day practice, thereby making good steel better.

THE PRODUCTION OF SOUND STEEL INGOTS.

THE physical properties of wrought steel depend in part on its chemical composition and in part on the mechanical and thermal treatment which it has received. The ingot is the phase in its manufacture in which it is prepared for physical treatment. The casting of sound ingots, simple though it may be imagined to be by those whose work begins with the finished bar or sheet, is a process literally as complex as the microscopic structure of the steel itself. In modern steel works practice the chemical composition of the metal can be identified and its heat treatment controlled with considerable precision and the effect can be followed closely by microscopical and other methods. The production of the ingot,

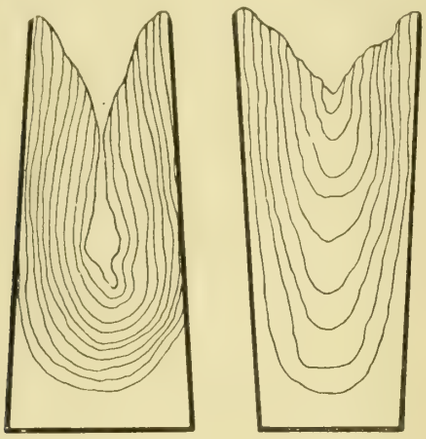


FIG. 1. FIG. 2.
GENERAL OUTLINES OF SUCCESSIVE LAYERS OF METALS IN INGOTS AS ORDINARILY CAST IN TAPERED MOULDS.

on the contrary, is subject to many influences to which quantitative determinations cannot be applied in practice, and it remains largely an empirical process.

The faults which occur in the production of the ingot do not necessarily disappear in its subsequent treatment. On the contrary, many of them may accompany the material throughout the whole of its manufacture and become either the reason for its rejection and consequent waste of labour or the hidden cause of disaster in use.

The Growth of an Ingot.—What occurs in the solidification of an ingot is generally accepted, but the actual form which the conditions of its growth compel its interior to take is not so generally recognised. The dominant fact is that the layers which set successively are roughly parallel to the walls of the mould, and preserve a similar inclination to each other. They are not accurately parallel, because the rate of cooling varies in different parts of the ingot. The sides of the outer shell which set first, for instance, contract and withdraw themselves from direct contact with the walls of the moulds, thus reducing their cooling effects, while the base remains constantly in contact with the bottom of the mould. This differential value of the cooling surfaces is appreciable, but is quite insufficient to prevent the inclination of the walls from controlling that of successive layers. This fact has recently been pointed out by Mr. Harry Brearley (Journal of the West of Scotland Iron and Steel Institute, March, 1916), and is both illustrated by him with reference to ingots which were emptied or bled at various stages of solidification and confirmed by a series of observations in the solidification of sterine, in which he was able to study the phenomena of cutting more closely and continuously than was practicable with metal.

Figs. 1 and 2 show the general outlines of the successive layers by which ingots as ordinarily cast grow in taper moulds. As is seen in Fig. 1, an ingot cast in a taper mould with its small end up forms ultimately a closed solid with a liquid in its interior. This liquid metal will shrink on cooling, leaving a pipe or cavity; and the cooling process, being there at its lowest, will favour the segregation or separate crystallisation of impurities along the central axis, while the solid closure of the cavity at the top will prevent the segregates from rising into the head of the ingot. A similar cavity is seen in both figures at the upper part of the ingot, and unsoundness through this cavity is avoided in practice by discarding the upper part of the ingot in which it is visible. Fig. 1 shows, however, that no such precaution will remove the unsoundness due to the lower pipe.

In both types of ingots the actual depth of the upper pipe will vary with the size of the ingot, the nature of the steel, and other circumstances. But in those cast with the large end up, drawing the shrinkage of metal from a larger cross-section, the depth of the pipe is less, while the longer time for which the metal remains liquid in the upper part permits a larger part of the segregates to rise into the head.

These facts are the more important because the convenience of stripping the moulds without waiting until the ingots are sufficiently set to be handled safely causes a large proportion of ingots to be cast with the small end up.

Top and Bottom Pouring.—The conditions of casting ingots differ also according as the metal is brought up into the mould from the top or the bottom. In top casting the mould can be, and usually is, filled more quickly than in bottom casting, where the liquid metal has to rise against its own head. As against this advantage, which is more material to quantity than to quality of output, bottom casting has advantages of its own. If the metal is introduced quite centrally and vertically through the base, it flows more evenly over the surface of the mould than if cast from the top, giving a cleaner skin and less chance of the premature solidification of splashes. The immediate contact of the metal with the sides and its relatively slow rise give a quicker setting and a thicker solid crust, reducing in this way the volume of liquid metal and the size of the pipe which its shrinkage will cause.

In a usual form of bottom casting the top of the mould is closed except for a vent hole; and the thick crust which forms through contact with the top serves to seal the ingot from the air and to give a better chance that the cavities which are left will be unoxidised and will weld up under the subsequent treatment.

In some practice the mould in bottom casting is left open at the bottom, and is placed over a hole in a thin runner-brick through which the metal is introduced. If the mould is not placed centrally over the hole, or if the hole is chipped

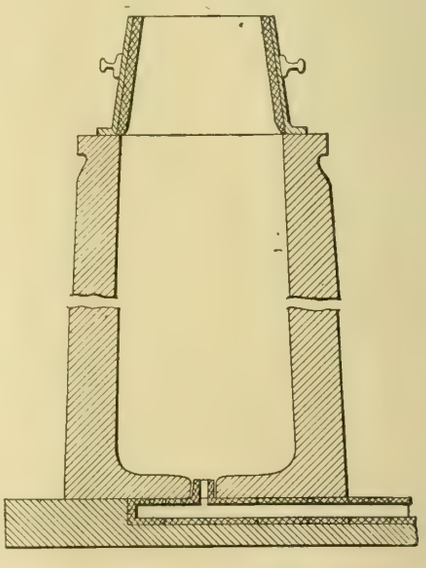


FIG. 3. INGOT MOULD WITH HOT-TOP AND LARGE END UP, SHOWING METHOD OF INTRODUCING STEEL IN BOTTOM POURING.

or partly melted, the metal is not delivered symmetrically into the mould, and under the head which is behind it may splash against the sides and otherwise set up lines of weakness in the ingot.

Modern Practice.—Leaving out the methods which have been and are used for closing cavities under pressure, which involves a costly plant and considerable revision of existing arrangement, the best known method of increasing the soundness of ingots and reducing the percentage which has to be scrapped is that of Sir Robert Hadfield. It has long been recognised that if the metal is kept liquid in the top of the mould, the pipe is fed and filled up to within a short distance below the final level of the liquid, while the segregates float up and are found in the head. In making small crucible cast ingots, for instance, the upper part of the mould is lined with a white-hot fire-clay sleeve or nozzle, which stops the piping, though not the contraction cracks.

A more vigorous method has been tried by covering the top of the metal with charcoal and burning it with a blast of air; but while this method gives the necessary heat and keeps the metal extremely liquid, it is apt to carbonise the upper layers of the metal and to introduce serious variations into the composition of the ingot. Krupp has covered the top of the ingot with molten slag. The solution of the problem which Hadfield has introduced is to use the charcoal and blast, but first to cover the metal with molten slag; thus providing whatever extra heat is wanted for keeping the metal liquid while interposing the slag to prevent carbonisation of the metal.

The use, however, of a separate blast on each mould introduces a complication to which many works would be averse, and obviously the method must require some care to prevent the charcoal from coming in contact with the steel which first solidified around the top of the mould and forming with it a liquid cast iron which would flow down into the ingot, which in the absence of precaution could readily happen when the level of the slag falls through shrinkage of the liquid steel.

Successful though the method has been in the works in which it has been used, an alternative would be preferred by many steelmakers in which no additional material and no extraneous heat is required. Such an alternative is now being worked in the following manner: The moulds are used large end up and the metal is cast from the bottom, which is solid (Fig. 3), having a central aperture fitted with a renewable fire-clay lining which stands over the hole in the runner-brick. This arrangement insures the metal being delivered

FIG. 4. FIG. 5.
FIG. 4 REPRESENTS AN INGOT AS USUALLY CAST.
FIG. 5 REPRESENTS A SECTION OF A 12IN. SQUARE INGOT POURED FROM BOTTOM IN A LARGE END-UP INGOT WITH A HOT-TOP.

truly up the axis of the ingot and avoids the troubles which ordinarily arise through inevitable defects in the runner-brick hole. By the use of a vacuum cleaner just before casting, any dirt which may have fallen into the mould is removed, and the ingots are obtained with a clean skin from the very bottom.

The top of the mould is covered with a cast-iron head with inclined sides, furnished with internal projections which serve to hold a thin refractory lining and the heat which this head catches and reflects on to the surface of the metal keeps the upper part of the metal liquid for feeding the body of the ingot as it shrinks until the segregates have passed up into the head and the ingot has set solid.

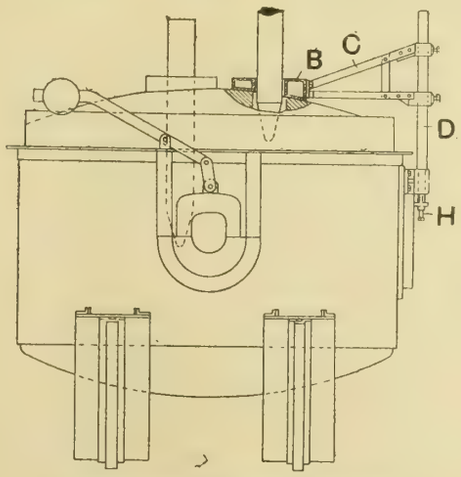
This process involves little or no alteration in existing methods of working. It is used in more than one works in Sheffield, England, and has been in constant operation for many years in at least one large steel plant in America, both for small and very large ingots. Sections taken from time to time have invariably shown an ingot sound up to the head, as is seen in Fig. 4, which reproduces the secton of a 12in. square ingot intended for conversion into shell billets and may be compared with Fig. 5 showing an ingot cast in the ordinary way. For the last eight months the same size billets made by this process have been adopted for rifle barrel blanks and supplied for this purpose with the rejection of only the head, which only weighs 10 per cent. plus or minus 1 per cent. of the whole ingot. The presence of any unsoundness or segregate in any blank is shown up at once on boring, and the observations on occasional sections have been confirmed by the fact that no rifle barrel blank has been found to be unsound.

Yield of Ingots.—The improvements in soundness of ingots which these modern processes have now made is therefore shown not merely by their conformity with the requirements of the physical phenomena of casting, but by prolonged and continuous experience. But the proportion of the upper part of the ingot which is scrapped in ordinary practice for many purposes including shells, remains for the most part unaltered. Under this practice a minimum of 20 per cent. is discarded from top-cast ingots and 25 per cent. from bottom-cast ingots, and is much more than is required to disclose a sound top in the part which is left for use. But even so, unsoundness may still possibly exist below the solid top. Considering the small control which the usual methods exercise over the inlet of metal in bottom-cast ingots and over the loss of heat and formation of pipes in ingots of both kinds, the practice as applied to them has not been needlessly severe.

As much, however, cannot be said of the application of this practice to ingots made under the modern processes which have been described. Taking, for instance, the figures of the last process, it is clear that after discarding 15 per cent. from the top of such ingots the whole of the suspicious region will have been removed, with an ample margin. No part of the remainder will be more likely to be unsound than any other part of the ingot; no further security will be gained by discarding a larger quantity, and the ingot so cropped will be far more likely to be sound than the ingots of ordinary manufacture which have been cropped in accordance with the present ordinary practice.—"The Iron Age."

BALMFORTH'S ELECTRIC FURNACE.

IT is usual in electric furnaces of the electrode type to cool the electrodes, where they pass through the roof of the furnace, by water jackets, which rest on and are secured to the roof. In this arrangement there is the drawback that considerable time and labour are spent in removing these jackets, whenever any repairs of the roof are required. An arrangement has recently been patented by Messrs. T. Balmforth & Co., Ltd., River Lea Boiler Works, Luton, Bedfordshire, in which the water jackets are not supported by the roof of the furnace, but are carried by arms adjustable on a vertical support so as to be swung clear of the roof at any time. An adjustment in a vertical direction enables the position of a jacket to be adapted to suit any changes in the height of the roof due to



BALMFORTH'S ELECTRIC FURNACE.

expansion and contraction caused by variations of temperature. The arrangement is shown in the illustration as applied to a furnace with three electrodes. The electrodes are surrounded, where they pass through the roof of the furnace, by water jackets B. Each jacket is supported by arms C, which are clamped in the required positions by screws to a vertical bar D, supported in a bracket fixed to the side of the furnace. When it is required to remove a jacket, the corresponding electrode is withdrawn, the jacket raised slightly, if necessary, by lifting the bar D by means of the supporting screw H and swung to one side about the axis of the bar D. The screw H also serves to adjust the position of the water jacket for any variations in the height of the roof.

RECENT STREET LIGHTING PROBLEMS AND DEVELOPMENTS.*

BY J. R. CRAVATH, M.W.S.E.

In order to consider recent street lighting problems and developments in their proper light we must necessarily constantly refer back to the older conceptions of the street lighting problem, many of which older conceptions still exist in the minds of the lay public, and to some extent among the members of the engineering fraternity who have not closely followed street-lighting matters.

The most noticeable change, to the layman, has been the change in the illuminants available. The open carbon arc lamp of 25 years ago gave way to the enclosed carbon arc lamp of lower efficiency and lower maintenance cost and this in turn is giving way to the luminous or magnetite arc lamp and the gas-filled tungsten incandescent lamp The low efficiency series carbon filament street lamp used up to about 10 years ago found but limited application in spite of the decided advantages of small units for the lighting of most residence streets. The series tungsten lamp, first in its vacuum and later in its gas-filled form, has within the last 10 years worked radical changes in the possibilities of proper treatment of residence street lighting, and the multiple tungsten lamp is found on hundreds of miles of "white way" on business streets.

The competitive street illuminant, gas, has also been doing its share of progressive work the past 25 years; the first and most important change being the mantle burner in its upright form supplanting the flat flame open burner. Later the inverted mantle and improvements in burner construction as well as in methods of maintenance have kept gas from giving way entirely to electric street illuminants.

In the electrical field just at present the two kinds of lamps which hold the supremacy are the gas-filled tungsten incandescent lamp and the luminous or magnetic arc lamp with the new high-efficiency electrodes. The flame arc lamp with long-burning electrodes as used in Chicago and some other cities has shown such a decrease of candle power due to fouling of the globes between trimmings as to put it out of competition with the two other lamps just mentioned. Its initial efficiency, however, is high.

Ideas as to the proper methods of rating lamps for street lighting have undergone radical changes along with our increase of knowledge as to the actual photometric performances of lamps and their accessories. It is impossible to adopt any one rating that will properly value a lamp for street purposes as there are such varied conditions to be met on different kinds of streets. There is, however, substantial agreement among leaders in illuminating thought and practice that all lamps of whatever kind, whether for interior or exterior illumination, should first be rated according to total lumens emitted; or upon what is the same thing differently expressed, viz., mean spherical candle power. This as a first step in uniform methods of rating is now being made, and is a great improvement over the old methods of rating by candle power in some particular direction, said direction sometimes being chosen to best suit the desires of the lamp salesman. On account of incandescent electric lamps having been rated so long upon a horizontal candle-power basis, and such candle powers having been included in many street-lighting contracts, it is still the practice of the lamp manufacturers to give the horizontal candle-power rating for series street incandescent lamps; but since the horizontal candle power of a gas-filled lamp with a coiled filament is an exceedingly variable, and difficult to determine, quantity, the practice is to give the rated horizontal candle power as one-tenth the total lumens of the bare lamp. Thus a lamp rated at 100 horizontal candle power is a lamp giving 1,000 lumens total light flux. This method of rating is approximately fair to all concerned, and in fact is about the only feasible way out of the difficult situation which arose when the introduction of coiled filament gas-filled lamps rendered horizontal candle power measurements so erratic. Those engaged in writing street lighting contracts, however, should incorporate the foregoing stipulations as to how the horizontal candle-power rating is obtained so as to avoid any possible future question on that point.

However, the rating of a lamp by total flux output in lumens of mean spherical candle power is now recognised as only the first step in ascribing the lamp a relative value for street illumination. It is important that the distribution of light flux be such that as large a percentage as possible is directed where it is most needed. The particular places where the greatest flux of light is needed or rather the particular angles at which the greatest flux should be emitted depends on the height and spacing of lamps and the nature of the roadway or pavement. In general, it is a safe rule to follow to get as much of the flux delivered midway between lamps as possible. It is conceivable that this might be overdone; but not with present appliances or under any common present conditions of street-lighting practice. Tests made by the street-lighting committee of the National Electric Light Association and Association of Edison Illuminating Companies in 1914 and 1915, indicated that discernment of obstructions and obstacles along a street might be less with nearly uniform illumination coming from a number of sources than with less uniform illumination coming from few larger sources. Conditions where an object can receive considerable light from a number of sources are only found on business streets and boulevards where the available expenditure per foot of street is much lighter than in residence streets. Residence streets constitute the far greater mileage and the most important problems in street lighting, and call for the most intelligent planning to get the best results on account of the small appropriations available. On such streets, there is no present danger that the uniformity of illumination or the multiplicity of light sources illuminating any one point will be so great that quick or easy discernment is less than it would be with a smaller number of large sources. In such locations the main question is how far can the lighting units be sub-divided and be kept within reasonable expense limits.

The auxiliary appliance (consisting of globe, reflector, or what not) that delivers as much of the light flux as possible on the street midway between lamps (but not very much beyond that midway point), is likely to be by far the most economical for most conditions, and the use of proper equipment of this kind is important. As a second step, therefore, in our process of rating illuminants we must consider the lamp as equipped with whatever auxiliary appliance may deliver the flux of light in proper proportion along the street for the given conditions in question.

Along with the rating of lamps comes the question of depreciation of the lamp under actual service conditions below the performance of the same lamp in the laboratory when new. This necessitates consideration of the actual blackening or fouling of globes in service and the amount that depreciation in service may be prevented by proper cleaning and maintenance. This depreciation is much more serious than commonly supposed, and should be watched. This brings us to the question of contract relations between lighting companies and municipalities to ensure proper maintenance. The time-honoured form of contract is to stipulate a certain candle power of lamp to be operated according to a certain lighting schedule at a flat rate of so much per year. In some contracts this has been wisely modified to stipulate a certain type and kind of lamp with possibly some further stipulations as to operating conditions and maintenance. Maintenance stipulations in most contracts are decidedly weak.

It was at one time proposed, and in fact recommended, by the 1907 and 1908 committee of the National Electric Light Association on street lighting, that street illumination be sold on the basis of the illumination obtained on a vertical plane about midway between the lamps. This recommendation, however, did not find favour in practice, and it is perhaps fortunate that it never did as it confuses the question of lamps and systems of illumination in an undesirable way. In 1913 a committee of the same association recommended that the desirable form of contract should specify definitely the kind of lamps and their performance, leaving the question of the proper spacing, equipment, height, kind of lamp, &c., to be determined in advance of the contract. Under such a procedure the lighting company would contract to maintain

* Paper presented before a joint meeting of the Chicago section American Institute of Electrical Engineers, Chicago section I.E.S., and Electrical section Western Society of Engineers.

and operate certain specified types of lamps up to a certain specified standard of service determined by candle power tests. It might be specified that such tests be made on the streets or by removal of street lamps to the laboratory and operating them in the laboratory under as nearly as possible actual street conditions. Such contracts should not be entered into, however, without a full knowledge of the actual street performance of the lamps in question. Extensive experience in checking street performance against the performance of new lamps in the laboratory causes me to urge extreme caution in this respect, as the discrepancies between these two performances are great in most cases. However, in some cases the existence of street performance tests has had a very marked effect in improving maintenance conditions. This improvement has sometimes been fully equal to that of a much heralded improvement in efficiencies of lamps as accomplished by the manufacturers. Lamp efficiency, therefore, is both a manufacturing and an operating matter, and every large contract should have some check on maintenance.

As to the broader economic aspects of street lighting contracts there have been some interesting recent developments. Public utility commission regulation in many states has helped to remedy conditions of over-charge and under-charge for street lighting service. Assuming that a public utility commission does its duty in a theoretically perfect manner, municipalities should pay continuously the actual cost of street-lighting service, including the depreciation caused by obsolesence of street-lighting lamps and apparatus due to the rapid changes in the street-lighting art. Such ideal conditions, however, have rarely been found in practice as yet and most critics are paying too much or too little for such service. In order to provide flexibility in a street-lighting contract a few contracts have been drawn, under which the city pays on a kilowatt-hour basis much like a private customer. If the city owns the lamps, it is then free to change the size and type of lamp as often as it may seem fit without the necessity of renewing a street-lighting contract or having a commission investigation. City ownership may even extend to circuits and poles with purchased energy. Equitable results should be obtained with either form of contract, and the choice must depend largely on the relative flexibility of the two methods in any given case.

I have left the most important changes in our conceptions of what constitutes the real problem of street lighting until the last. How are lamps to be spaced, how high are they to be mounted, and how equipped as to globes and reflectors, to give the best discernment of objects along the street, with the best general appearance; or if the questions of easy discernment and pleasing appearance are not answered in the same way, what point of compromise shall be adopted? An early idea was that the effectiveness of a system of street lighting depended mainly on the total candle power of the lamp placed along a street without much regard for the height, distance apart, equipment, or size of each unit. Later, more scientific ideas were advanced, based on the illumination along the street. Ten or fifteen years ago, vertical illumination was the chief thing considered in street lighting. Later horizontal illumination on the street surface received more consideration. All of the following have been proposed as criterions for the value of a system of street illumination: (1) Minimum vertical illumination between lamps; (2) average vertical illumination; (3) minimum horizontal illumination; (4) average horizontal illumination. None of these is sufficient, and all of these together would be incomplete for the reasons given later, but if one is selected as a practical working measure for residence streets at the present time, minimum vertical illumination between lamps would probably be as good a criterion as could be established, and minimum horizontal illumination for business streets, but these are far from taking into account all of the conditions which influence clearness of vision. In the year 1910 two memorable contributions to the literature and knowledge of street lighting were made. One of these, by Mr. Preston S. Millar, before the Illuminating Engineering Society, showed that a considerable portion of our seeing by street lighting at night is by virtue of the silhouette effect, whereby objects are seen as dark silhouettes against a light surface background. Illumination of the street surface rather than the vertical objects on it is necessary for this.

The other contribution was by Mr. A. J. Sweet in the Journal of the Franklin Institute, in which the blinding effects of glare were studied. The blinding effect of glare, that is, the effect of a row of lamps within the line of vision when looking along a street at night, renders ineffectual a certain percentage of the light expended upon the street for the purposes of illumination, because it decreases the ability of the eye to see. The existence of such an effect is easily demonstrated by anyone, but quantitative measurements of it were first published in 1910 as stated, and have since been studied in more detail by Mr. Sweet.

We see objects along a street at night just as we see all objects at any time, namely, by virtue of differences in brightness and colour of their surfaces. A study of silhouette effect in connection with this fact leads to some interesting results. As stated, a considerable portion of our discernment at night is by virtue of this silhouette effect. Fortunately, the reflection from paved surfaces is greatest at very oblique angles, so that, as shown by Millar, the brightness of a street surface is much more nearly uniform than would be indicated by a measurement of horizontal illumination. All this helps to make a uniform background for a silhouette effect.

The avoidance of glare effect (which in common past practice may easily be such as to call for from 1·2 to 1·8 times the illumination that would be necessary if glare were not present) is partially accomplished by increasing lamp heights. Good practice now mounts lamps from 16ft. to 25ft. and even 30ft. in height, where formerly heights from 10ft. to 14ft. were employed.

As to how far it is feasible to reduce the blinding effect of glare materially by the use of refractors which reduce the flux of distant lamps entering the eye, without too much darkening of the street surface between lamps, is a point upon which conclusive demonstration may be looked for soon. That a partial solution of the difficulty is feasible there is no doubt.

METAL QUOTATIONS.

TUESDAY, OCTOBER 24TH.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled..	1/4⅛ per lb.
,, tubes (brazed)	1/6¼ ,,
,, ,, (solid drawn)	1/4¼ ,,
,, ,, wire	1/3⅝ ,,
Copper, Standard	£123/10/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£32/5/– ,,
,, Foreign (soft)	£30/–/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	32⅛d. per oz.
Spelter (American)	£51/–/– per ton.
Tin, block	£180/–/– per ton.
Tin plates, I.C.	32/6 per box.
Zinc sheets	£72 per ton.

The Junior Institution of Engineers.—The activities of the winter session commenced on Friday, October 6th, when Mr. E. Eade opened the series of Friday evening "informal discussions," taking for his subject "Stability and Use of Cranes under Working Conditions." During October similar lecturettes will be given on "Principles and Application of the Oil Engine" by Mr. W. H. Abrahams, and "Time Saving as a Science" by Mr. A. H. Stanley. The ordinary monthly meeting was held on Wednesday, October 18th, when Mr. Frederic H. Taylor, A.M.I.E.E., A.M.I.M.E., read a paper on "Industrial Lighting by Electricity." A special series of five lecturettes will be given on alternate Friday evenings from October 20th by Mr. E. Fiander Etchells on (1) "A Commonsense Notation for Engineers," (2) "The Practical Use of Units in the Evaluation of Formulæ," (3) "How to Memorise Formulæ," (4) "Logic of the Differential and Integral Calculus," (5) "Practical and Illustrative Examples of the Application of the Newer Concepts."

CORRESPONDENCE.

Fuel Economy on the North-east Coast as a Result of Electric Power Supply.

To the Editor of "The Mechanical Engineer."

Sir,—The paper on this subject by Mr. R. P. Sloan, reported in your issue of the 13th October, as read before the British Association at Newcastle-on-Tyne, on September 8th, 1916, is a valuable contribution to the question of fuel economy, and probably it will be regarded by engineering experts as quite satisfactory from a technical or theoretical point of view. In so far, however, as Mr. Sloan's observations convey to your readers the impression that the waste heat problem has been solved in favour of the general users of power on the North-east Coast it is somewhat misleading.

However great the saving of fuel may be by the utilisation of waste heat in the production of electricity, and whatever future economies may be effected by other means by the reforms at present being devised by the experts of the Institution of Electrical Engineers, cheapness of production does not mean a cheap price to the users of power in the North of England in the extensive areas operated by the Cleveland and Durham group of power companies extending to the counties of Northumberland, Durham, and Yorkshire.

By selling practically all its shares in 1906 to a holding company, the parliamentary company, the authorised undertaker, having extensive rights and obligations on the North-east Coast, has delegated these rights and obligations to the holding company, which is expressly forbidden by Section 11 of the Electric Lighting Act, 1882, and Section 14 of the Electric Lighting Act, 1909. Thus the authorised undertaker is no longer a free agent to make its own electricity, or to buy in bulk in the best market. The holding company controls the whole bulk supply and compels the parliamentary company to take its supplies from the holding company at the holding company's price. It therefore follows that the question of price to the consumer is in the hands of the holding company, which has neither obligations or rights under the Electric Lighting Acts, and can divert either to itself or to its friends all the profits of the authorised undertaker, or as much as it thinks fit. Under these conditions what value are the statutory accounts meant for the protection of the public, and of what use are the clauses in the Electric Lighting Acts regulating prices and dividends? Who is to hold the scale between this powerful organisation and the consumer when that organisation can buy other companies ad lib. to snatch the main profits of parliamentary undertakings as the waste heat plant lending company has done.

Not only has the holding company compelled the parliamentary company to take its bulk supply of electricity at its own price. It has compelled the parliamentary company to buy large quantities of plant at a price giving tens of thousands profit to the holding company by adding a paper value to the parliamentary company's plant. Year after year this paper value in excess of cost has remained in the parliamentary company's statutory accounts, while the holding company's directors, as the sole shareholders and directors of the parliamentary company, which has a million authorised share capital, have passed and declared dividends from the parliamentary company, which have been used to pay the attenuated preference dividends of the holding company. The directors of the holding company, as the sole shareholders of the parliamentary company, vote to themselves their own fees, re-elect themselves directors, appoint auditors, and go through the form of passing resolutions required of proper shareholders. This is the business burlesque vaunted by the directors of this influential organisation, as worthy of the best traditions of British enterprise.

This powerful combination when repeatedly challenged in the Press has had no public justification for its antics. The Board of Trade has reported that the authorised undertakers are "undertakers in name only," but under existing law the Board of Trade do not appear to have the power to apply a remedy. What therefore is the first step to remedy other than putting pressure on Parliament to thoroughly investigate the whole matter? What prospect is there of the proper benefit of future economies reaching the collieries, iron works, shipbuilding yards, engineering establishments, and the numerous other industries on the North-east Coast under present conditions?—I am, yours faithfully,

ANDREW GEMMELL

(A former secretary to electric power companies).

Ovingham-on-Tyne, October, 1916.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Heating furnaces. Hislop & Hislop. 5040.
Lathes or boring machines. Andrew & Barraclough. 9475.
Rotary compressors and exhausters. Johnston, and Globe Pneumatic Engineering Company. 12360.
Carburetters of internal combustion engines. Bergasse. 15139.
Annealing furnaces. Morris. 16212.
Ships. Ouimet. 16467.
Soldering of aluminium or aluminium alloys. Overend, Grinlinton, and Overend Aluminium Soldering Processes, Ltd. 17118.

1916.

Valve gear for internal combustion engines. Concaris, A. 201.
Fluid pressure braking apparatus. Westinghouse Brake Company. 589.
Slide rests for turning lathes. Oldaker, M. S. 791.
Machines for screwing and tapping metals. Collis, A. 795.
Riveting apparatus. McMillen, R., McMillen, A., and Workman, Clark, & Co. 1078.
Internal fittings for boiler tubes. Henderson, T. 1579.
Railway signalling apparatus. O'Donnell, J. P. 5673.
Method and means of using paraffin or crude or heavy oils in internal-combustion engines. Wilkinson, F. A. 5921.
Carburetting apparatus for internal-combustion engines. Johnson, E. W. 6577.
Turning lathes. Cone, F. L. 6820.
Vaporisers for internal combustion engines. Robinson, R. P. 6824.
Engine cylinder for single acting combustion engines. Kilburn, B. E. D. 7338.
Railway-signalling apparatus. O'Donnell, J. P., and Knox, H. S. 8577.

ELECTRICAL, 1915.

Means for minimising sparking at break of a circuit containing inductance and capacity in series. Wall. 13568.
High frequency dynamos. British Thomson-Houston Company. 13904.
Electro magnetic power transmission apparatus. Neuland. 13912.
Dynamos. Neuland. 14160.
Dynamos of the commutator type. Walker. 14216.
Portable telephone and telegraph instruments. International Electric Company, and Le Noir. 14232.
Telephones. International Electric Company, and Le Noir. 14233.
Alternating-current electric motors. Shaw, Shaw, & Sharp. 14650.
Systems of electric welding. Wilson, Andersen, & Curtis. 17833.

1916.

Current limiters or electric interrupters. Pettersen, K. 894.
Sparking plugs. Lamkin, A. E. 5240.
Electrolytic cells. Churchill & Co., C., and Geeraerd, E. 6735.
Means for earthing electric conductor conduits. Rushton, G., and Lacy, L. R. 7347.
Method and apparatus for varying the pressure in electro-magnetically-operated carbon pressure regulators. Akt.-Ges. Brown, Boveri, et Cie. 8698.
Electric couplings. Allmanna Svenska Elektriska Aktiebolaget. 9745.
Electric cable joint boxes. Vernier, C. 10554.
Means for telephonic communication to and from moving railway trains. Werner, V. G., and Warfvinge, K. H. 11658.

Institution of Civil Engineers: Awards.—In addition to the awards already announced the Council have made the following awards for papers published in the Proceedings without discussion during the session. 1915-1916: Telford Premiums to Messrs. Hubert Mawson (Liverpool), T. W. Keele (Sydney), R. W. Holmes (Wellington, N.Z.), W. Fairley (London), J. M. Greathead (Johannesburg), T. C. Hood (Manmad, India), and J. B. Ball (London); the Manby Premium to Mr. W. C. Cushing (Pittsburg, U.S.A.); and the Crampton Prize to Major C. E. P. Sankey, D.S.O., R.E. (London). The Indian Premium for 1916 has been awarded to Sir John Benton, K.C.I.E. (Eastbourne).

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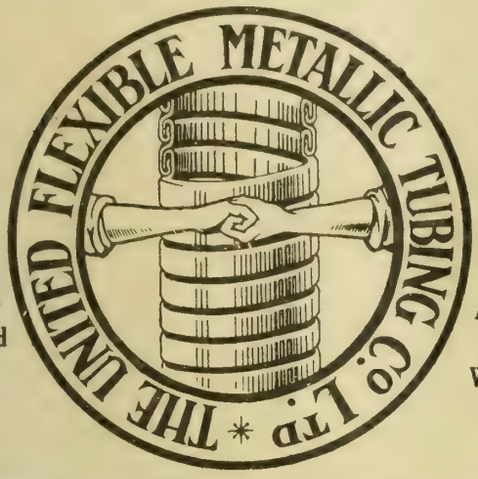

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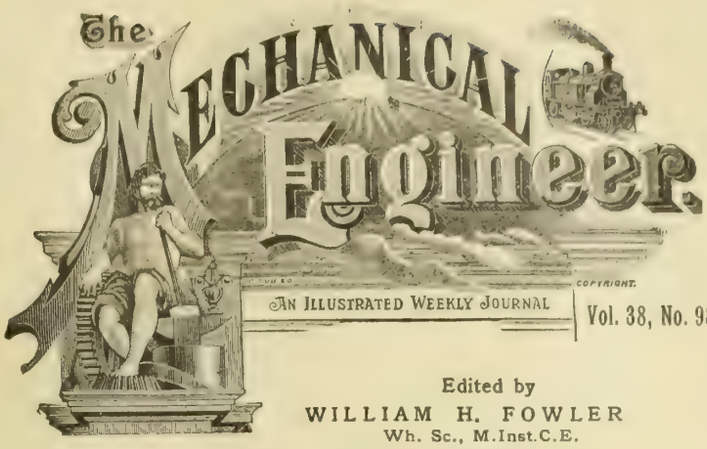

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Production and Competition.

In his address to the Institution of Mechanical Engineers, on the occasion of his accession to a second year of office, Dr. W. Cawthorne Unwin, the president, took occasion to refer to some criticisms by Dr. Dugald Clerk on certain remarks in the course of his first presidential address on the relative industrial development of Great Britain and Germany. As we commented on these at the time (see our issue for November 26th last), it is but reasonable that Dr. Unwin's reply should also be presented. In his first address he urged that Germany, since the war of 1870, had progressed in many industries much faster than we had done, and quoted figures, mainly in connection with the steel industry, to support his view. It was to these that Dr. Clerk mainly devoted his attention in the course of an address delivered shortly afterwards to the Royal Society of Arts. There was no question as to the accuracy of the figures of pig iron production, which in Germany increased from 11 to 19 millions, while ours only increased from 9 to 11 millions. In the course of a quarter of a century Germany's production of pig iron has trebled, while her steel production has sextupled, and is now two and a half times as much as our own, the figures for 1913 being 18 million tons, as against our 7 million tons. As we pointed out, however, in our previous reference, Germany's steel production has been mainly the result of the Thomas Gilchrist process, a British invention, which enabled her to utilise the phosphoric ores, which constitute her main source of raw material, and which, prior to this invention, were useless for steel making. In this country owing to the mistrust, and possibly a certain degree of prejudice, attention has been more concentrated on acid steel, as being more suitable for the higher grades of steel mainly used in our industries. Figures of steel production, therefore, are not an altogether reliable indication of industrial progress. This is not put forward to discount any

legitimate progress that Germany has made, or to excuse any shortcomings in our own methods, but in making any comparisons it is necessary to take qualifying conditions into account. Dr. Clerk pointed out that Germany's pig iron output was almost a matter of home consumption in railways, and uttered a general protest against the pessimistic tendency to view in an unfavourable light British achievements in science and industry. He had little difficulty in supporting his protest with striking examples, and his address was invigorating and a healthy corrective to the stream of pessimism. Dr. Unwin returns to this question of steel rails, and in reply to Dr. Clerk's explanation that the enlarged steel output in Germany was due to the latter country having 38,000 miles of railway, as against our 23,000 miles, remarks that in India there are also 33,000 miles of railway, as well as railways in other Colonies, mainly built and maintained by the use of English steel, so that Dr. Clerk's railway mileage test does not explain the difference. This may be so, but equally it does not establish the converse. In 1912 Germany exported a million tons of pig iron, and four million tons of steel partly manufactured, towards which we partook of 7½ million pounds worth. It may be, and probably was, the case that much of this was for basic steel imported and re-exported to India and the Colonies. Without considerable analysis it is impossible, of course, to determine this, and is scarcely worth pursuing as it does not affect the leading features of Dr. Clerk's case. A more important point is a consideration of the methods by which Germany has succeeded in infiltering her trade into countries abroad. Some of these may be worthy of imitation, but others are undoubtedly unscrupulous, and should be scotched by all legitimate means. There is a general opinion amongst economists that German foreign trade has been largely promoted by their system of Kartels formed after their adoption of rigid protective legislation in 1879. One of the greatest of these is undoubtedly the steel union, which embraces 31 firms of an annual output prior to the war of 12 million tons or practically two-thirds of the entire production. The ostensible object of the Kartels is to reduce cost of production and competition between its members. Another equally important one, but not admitted, is to acquire monopolies, and impose its own price on customers whether at home or abroad. Behind its protective barrier the Kartels are within limits easily able to impose their price on the home market. Abroad conditions are not so favourable, and to overcome the competition they resort to methods of "dumping," which if not exactly illegal or immoral, judged by the standards of trade intercourse border close on it, and in their execution are certainly unscrupulous, and striking instances have been given from time to time. Figures show that girders and rolled bars which were sold in Germany at 130 marks were sold in England and South America at 103 to 110 marks, and in Italy even as low as 75. It may be argued the seller alone suffers by this increase of price, and the buyer has every inducement to encourage the policy. This reasoning is true so long as the policy is continued, but the Kartels do not set out with any such intention. The low prices quoted by them do not spring as they may legitimately do occasionally from an accidental surplus arising from over production, but from a deliberate intention to ruin a competitor, and then to run prices up to a higher point before cutting began. The cutting, when indulged in in this way, is but a temporary expedient made at the expense of a home market in order to stifle a foreign one. There is no doubt the artifice has, in many directions, succeeded, and as to its unfairness there cannot be two opinions. How best to prevent it is another matter which requires careful consideration, but it is certain that effective remedies cannot be imposed by private individuals unless it is backed by legislation. Combination and organisation may promote industrial efficiency in many ways by eliminating wasteful competition and promoting economy of production; and in view of latter-day developments most people are agreed that co-operative methods might be used to a much larger extent in this country to the advantage, not only of employers and workpeople, but the general public also. One thing, moreover, is certain, that to meet the enormous demands upon our wealth which will arise out of the war, our methods of producing it will have to be developed to the highest degree and the brake that has hitherto been imposed on our output by the continual struggle between capital and labour must be removed. There can be no hope of supremacy in the future industrial struggle unless the restrictions of output, which the trade unions bargained should be restored after the war, are abolished. They are as immoral and unfair in their effects as any actions of the German Kartels and in the long run are sure to prove as ineffective. The more wealth we create, the more we can divide among ourselves, and the larger the surplus to wipe out indebtedness or pay for foreign goods.

DIESEL ENGINE USERS' ASSOCIATION.

THE first of the autumn meetings of the Diesel Engine Users' Association, after the summer recess, was held on October 20th. After the election as members of the association of several engineers having the control of Diesel engine plant, certain resolutions were passed providing for alterations and additions to the rules. From the end of the current year an entrance fee of one guinea is to be charged to all new members elected. To meet the demand, which has arisen in many quarters, for copies of the reports of proceedings, and of the general information and data circulated by the association, provision has been made for a class of "subscribers." Such "subscribers," who must be duly accepted by the committee, would consist of individuals or firms who are not qualified for full membership, and would be entitled to receive the particulars circulated on payment of a sum of one guinea per annum. They would not be entitled to attend the meetings of the association (except by special invitation of the committee), neither would they have any voice in the control of the association. "Subscribers" may, at any time, send communications to the honorary secretary, and if in the opinion of the committee they are of general interest, such communications may be read and discussed at a meeting of the association.

Air Compressor Explosions and Troubles.—The committee presented a report on the subject of explosions in air compressors, and on the various troubles experienced with air compressors, having special reference to the accident which occurred at the Generating Station of the Smithfield Markets Electric Supply Company, Ltd., in February last. After discussion on certain points this report was adopted by the association, and it is, in due course, to be printed and circulated among the members.

Tar Oils as Fuel for Diesel Engines.—Mr. Napier Prentice gave further information in connection with the application which had been made by the Suffolk Electricity Supply Company, Ltd., for the voidance or suspension for the duration of the war of the Konrad Aust Patent in connection with the use of tar oils as fuel in Diesel engines. He considered that on national grounds such action should have been urged or supported by a Government Department. Since the application has been made, however, his experience in the use of tar oils in Diesel engines, without the fitting of any pilot ignition, had been so satisfactory that he did not think it would be advisable that his company should incur any costs in connection with the adoption of the method of working covered by the patent. He was now effecting a saving of about 50 per cent. in fuel costs by the partial use of tar oil.

Mr. Geoffrey Porter (president) gave particulars concerning a pilot ignition apparatus which had been fitted to a Diesel engine at Worthing. The saving in fuel costs obtained by using tar oil in this manner, with about 10 per cent. of crude

oil for the ignition charge, amounted up to date to about 47 per cent. The only trouble experienced had been in connection with the formation of a deposit which choked the pulverisers. No trouble had been experienced with the exhaust valves or with the needle valves. He also stated that he had tried on another engine a mixture of three parts of tar oil to one of crude oil. The engine had knocked rather heavily, but at three-quarters of full load, and with fairly continuous running, no further troubles had been experienced. He, however, did not favour the use of mixtures of tar oil and crude oil. There was some risk of mis-firing, and there was a difficulty in securing complete mixture of the two classes of fuel oil.

Mr. W. A. Turnbull stated that he had worked a Diesel engine on tar oil with a slight alteration to the flame plates, and he had obtained a saving of about 50 per cent. in fuel costs. He had not noticed any corrosive effect by the tar oil on the copper pipes or brass fittings.

Further information of actual experience in the use of tar oils was given by Messrs. F. W. Strickland, J. Broadhurst, and W. Fennell.

Mr. Napier Prentice strongly urged that on national grounds, as well as in their own interests, Diesel engine users should continue to endeavour to make use of home products of fuel oil to the greatest possible extent in preference to fuel oil imported from abroad.

SOME EXPERIMENTS IN NATURAL-DRAUGHT OIL BURNING.

LIEUT. L. R. FORD, U.S.N., in an article in the August issue of the Journal of the American Society of Naval Engineers, gives an interesting description of experience in oil burning on the U.S.S. "Fulton." At the time the ship was commissioned, the steam necessary to operate the auxiliaries was supplied by a Roberts water-tube boiler equipped with one large burner, which used either steam or air as an atomising agent. The air for combustion was supplied by natural draught through two small ventilators and through the door between the engine room and fire room. After a disastrous furnace explosion, due to the burner flame being extinguished and the furnace becoming filled with explosive gas, which ignited, the boiler was fitted with two of the Bureau's standard type air registers and burners. These burners atomise the oil mechanically and are designed for use with forced draught. In addition, a second boiler of the Almy water-tube type was installed, which made the room quite crowded and curtailed the already limited air supply.

As soon as the ship was ready to leave the Navy Yard troubles began. When the burners were lighted under one boiler, it became evident that the combustion was very poor. Several schemes were resorted to. Small portable electric blowers were placed on the fire-room floor plates so as to discharge against the registers in the furnace front. This helped only slightly. A sheet-metal box built on the boiler front so as to completely enclose the registers and burners, and connected with two $\frac{1}{4}$ h.p. portable blowers proved to be a failure. A small box was then built that would stand on the floor plates in front of the burners, with the two $\frac{1}{4}$ h.p. blowers connected so as to discharge into the box. This improved the combustion, but far from sufficiently. So much soot was deposited that it became necessary to establish a routine requiring that the tubes be blown with steam once every hour or 24 times each day.

The oil pressure habitually carried with the Bureau type of burner was 200lbs. It was found that by reducing the oil pressure much better combustion was obtained, but the oil was then insufficient to maintain the steam pressure. Several types of experimental burners with either air or steam atomisation were tried, but without much success. Finally, the following system was adopted on the advice of Lieut. A. M. Penn, U.S.N., in charge of the fuel-oil testing plant at the Navy Yard, Philadelphia.

The Bureau standard type registers were removed from the furnace front of the Roberts boiler and a bar of $\frac{3}{4}$in. by 3in. flat iron was supported across the front of each opening in the furnace front on $\frac{3}{4}$in. studs, these studs projecting 10in. from the furnace front and being provided with threads and nuts for adjusting the bar for distance. Each bar was drilled at its centre large enough to permit the insertion of a burner. The burner itself was modified as shown in Fig. 1. A funnel shaped diffuser was made of sheet iron and attached to the end of a piece of $1\frac{1}{4}$in. pipe, 4in. long, by means of a band clamp. This clamp method of securing the diffuser on the pipe was preferable to screws or rivets, as it permitted easy removal of the diffuser. The included angle of the diffuser was selected after several experiments as 90°, and the diameter at the large end was made $4\frac{3}{8}$in. The pipe was slipped over the tip in such a manner as to permit adjustment of the distance the burner tip projected into the diffuser.

When this burner was lighted a most interesting action was observed. With the diffuser drawn well back towards the rear, the flame would jump away from the burner, but when the diffuser was pushed forward it would pick up the flame, and a short cone of clean flame would result. When the diffuser was adjusted to the best operating position, a halo of white flame would appear around the edge, as shown in

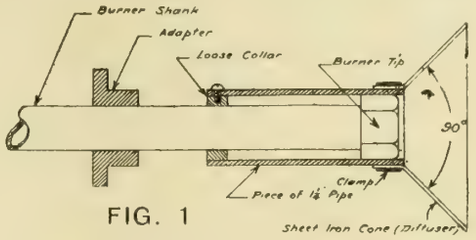


FIG. 1

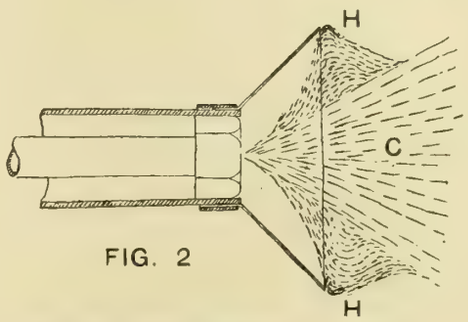


FIG. 2

IMPROVED NATURAL-DRAUGHT OIL BURNER.

Fig. 2. The main body of the flame retained its cone shape, as shown at C, this cone of flame extending back to the burner tip; but part of this flame seemed to draw out to the diffuser and curl down from the edge, as shown at H. The combustion obtained with this arrangement was very good indeed.

Among the modifications introduced were the installation of vertical fins of thin sheet metal in the shape of a helix around the circumference of the conical openings in the furnace, to promote mixing of air and fuel by giving the entering air a rotary motion. Another improvement was the mounting on the head of the oil line a large air chamber. This chamber kept the oil pressure steady, the effect of which was quickly noted at the burners. When the diffusers were adjusted to get the halo around the edges, it remained there without further adjustment. What surprised the ship engineers most was the low oil pressure required to maintain the steam pressure and the wide range of pressure through which the burners could be operated smokelessly. Under the old conditions it had been necessary to operate the burners under an oil pressure of 200lbs. It was now found that the steam necessary to meet the normal demand of the ship could be evaporated with an oil pressure of 50lbs. to 100lbs., and the pressure had to be raised to 200lbs. only when an extra demand for steam was made. In fact, it was found that the steam pressure could be quickly and closely regulated by varying the oil pressure, which could be done by varying the spring tension of the regulator valve on the oil pump. Steam control was thus reduced to the mere screwing of a nut up and down with a wrench, a novelty which strongly appealed to the fireman.

The helical vanes, in addition to giving the air a rotatory motion and thereby promoting mixture of air and oil, serve a useful purpose in intercepting the radiant heat from the flame. It is found that since they were installed the heat in front of the boiler is now greater than when the closed registers were in use.

WORKS ORGANISATION.*

BY A. D. C. PARSONS, B.A., EDWIN L. ORDE, AND G. H. TWEDDELL.

(*Concluded from page 320.*)

PART II.—THE FINANCIAL ORGANISATION OF FACTORIES.

BY EDWIN L. ORDE.

THE members of this institution are for the most part interested in shipbuilding and engineering work, where the form and quantity of the products vary widely, and they will therefore appreciate the difficulty of writing a paper on financial organisation which is of more than general application. The evolution of accurate cost accounts seems to have begun at the time when competition began to influence sales, and to prove the superior efficiency of large factories, finding its highest development in factories where machine work can be most largely utilised. The various stages in the evolution are long, and until lately, technically trained engineers have been too apt to look on accountants with kindly tolerance, rather than as valuable allies. This is probably due to the jealousy, with which in former years everything to do with the counting-house was guarded, as was perhaps necessary until good systems of accounting were devised which divided into classes the information required by various departments, and could present it without disclosing any part of the accounts which should be kept private.

It is to be supposed that the ordinary book-keeping of factories has been considered so long and so carefully that nothing better is required to-day than one of the good existing systems. The costing and estimating departments cannot perhaps be considered with so much complacency, for unless advantage is taken of new developments and improvements, the work will suffer by comparison with modern methods and this will be reflected in the order-book.

Some examples of early estimates for ships are given, which are interesting as showing the simplicity of the costing system then in use and the short cuts which apparently could be taken by managers who practically carried on the whole of the manufacturing and selling sides of their business themselves. They had their own methods, or perhaps instincts, which aided by large margins were apparently sufficiently accurate in many cases; although the large number of failures which have occurred in the history of this district seem to show that the human element was not always sufficiently infallible. As powers and dimensions of engines and ships increased, the early forms of estimating were naturally found inadequate; more detail in the costing system became necessary, and the part played by the accountants' department assumed a very real importance which must grow as new problems arise for solution.

The primary object of all costing systems is to obtain a record of the amount of money spent on labour and material, to ascertain the proportion of the expense of working the factory to be added to these two items and to present (1) The total net cost of every production, and (2) Such divisions and subdivisions of the cost as may be considered by the management most likely to enable a close scrutiny of working processes to be made, and a continuous comparison with corresponding items in the estimates. Four essentials of a good costing system are: (1) Accuracy. (2) Simplicity. (3) Rapidity. (4) Elasticity.

This seems sufficiently obvious, but writers on these subjects complain that elaboration of detail is only too apt to increase to a point where the cost of working the system becomes unduly high. The case of Woolwich Arsenal is quoted, where in 1906 over 4 per cent. of the total wage bill was spent on clerical administrative labour. The total wage bill is not given, but from other figures it may be deduced that it was of the order of £1,500,000.

Time.—Accuracy in recording time is of the first importance and at the same time most difficult to ensure. When work is constant and is paid on piece rates, the returns are probably as correct as is necessary, but when a man on time rate is employed on a number of comparatively short operations for various orders, the difficulty of accurate record becomes greater and attempts to meet it probably costly. As a general principle it would seem that foremen should be involved in the time-keeping system to an extent which shall influence them in spreading the work as evenly as possible, so as to avoid the difficulty referred to above, but at the same time shall not interfere to any harmful extent with their real function, the distribution and technical supervision of the work. It is impossible to point out any system of time keeping as being the best. The exigencies of the particular factory are the sole guides to the method and the amount which may be usefully spent upon it, but accuracy of a high order should be aimed at.

Stores.—A great deal of attention has been paid to the storehouse by various writers, as it constitutes a possible source of leakage which is difficult to detect unless the cost system is carefully designed and applied. A well-arranged system of cards seems to offer the best solution and to give the clerical department complete information in a form which is readily accessible. The card system has many advantages over books, can be applied to any department, and is elastic in that it can be quickly and easily adapted to a change of process or new variety of work, but it seems to the writer that in the designing and application of the system there should always be the closest possible collaboration between the accountants' department and the technical management.

In fluctuating markets the storehouse requires considerable attention, for the adjustment of the rates at which various articles should be issued must exercise an important effect on the cost of the product and on future estimates. As a general rule it seems that the market rate at the date of issue or at the nearest date that can conveniently be ascertained should be taken and any profit or loss dealt with in the stores account. Unless this is done direct comparison between the market rates and the cost of the product becomes impossible and future estimates based on these costs are misleading.

Materials.—Materials ordered direct for contracts pass through the ordinary books required by the system in use, and materials for stock through the storehouse or yard and can be suitably recorded on cards.

Estimating.—Much has been written on the superiority of American methods of costing and estimating, and so far as the writer has been able to ascertain they possess the attractive feature of rapidity. There can be no doubt that the best way of obtaining accuracy is to be found in a system which enables results to be recorded before many days have elapsed after the work is finished, and the details are still fresh in the memories of those concerned in it; while the estimating department have the knowledge that the net costs on which their work is based are the result of immediate enquiry and investigation when discrepancies occur and so can be used in a new estimate without any misgivings. Another feature of what may be called the American system of estimating is the employment of technical men as estimaters both of quantities and rates. These technical men generally specialise in one main department or group of departments, analyse net cost figures, bring them up to date, and work them into forms which they find most suitable for preparing estimates for the cost of work carried on in their own special department, and in the highest development of the system fix rates for various classes of work. There seems to be some advantage in the system, in that: (1) Technical peculiarities which might prevent the figures from the net cost of one contract serving as a basis for another, might pass unnoticed by any non-technical man and so spoil an estimate. (2) The technical estimating staff are in constant touch with the net cost system, and should be able to devise methods of presenting figures to the management which can be prepared by the net cost clerks and so keep the present and future work on a correct cost basis.

On the other hand, the system must be costly if it is really to be efficient, though this will be perhaps recouped in works where there is much estimating to be done, by the accuracy and rapidity which must be attained by such a system in the hands of competent men. It is said that the inherent weakness of the system of estimating in general use in this country, *i.e.*, the calculation of quantities by technical men and rates by net cost clerks, lies in the difficulty experienced by the net cost clerk in fixing his rates judiciously, owing to his lack of technical experience, and this is urged by the advocates of what has been called the American system.

It is impossible in this, as in other details of financial

* Paper read before the North-east Coast Institution of Engineers and Shipbuilders.

organisation, to dogmatise or to fix on any one system which is applicable to every factory, but the writer considers that a judicious blend of the estimating draughtsmen and net cost clerks can be made which will bring out the best qualities of both departments, and so produce sufficiently accurate estimates for presentation to the managers who are responsible for the cost of carrying out the work, and should therefore examine all estimates before they are used for tendering.

The system of doing the whole of this work by means of a technical staff has an advantage over the net cost clerk system in this respect; that the technical staff, when not actually engaged in estimating, can be occupied in watching net costs as the work progresses, and in devising means whereby they can be compared with the estimates at all stages, so as to keep the management closely in touch with the financial aspect of the operation. This, in the writer's opinion, is the most important point in financial organisation.

A close comparison between the cost of work in progress and the estimate is, of course, difficult to make, unless a large and consequently expensive staff is maintained for the purpose, so as to ensure that the wages can be quickly abstracted and compared with the corresponding items in the estimate, without allowing so much delay as to make it possible for grave differences to occur without being noticed. This can to some extent be arranged in shipyards by plotting cost progress curves, of which the ordinates represent money, and the abscissæ time. If the scales are judiciously chosen, the estimate curve can be made to assume so definite a character that any marked difference between it and the actual cost curve, when it is plotted, can be seen, probably one or two weeks before it begins to assume serious proportions. Fig. 8 gives an actual example where the steel wages are taken as a measure of the progress of a ship up to the date of launch. A system of this sort can be applied to other trades, and constitutes a valuable check on the progress and cost of the work, without entailing an extravagant clerical staff.

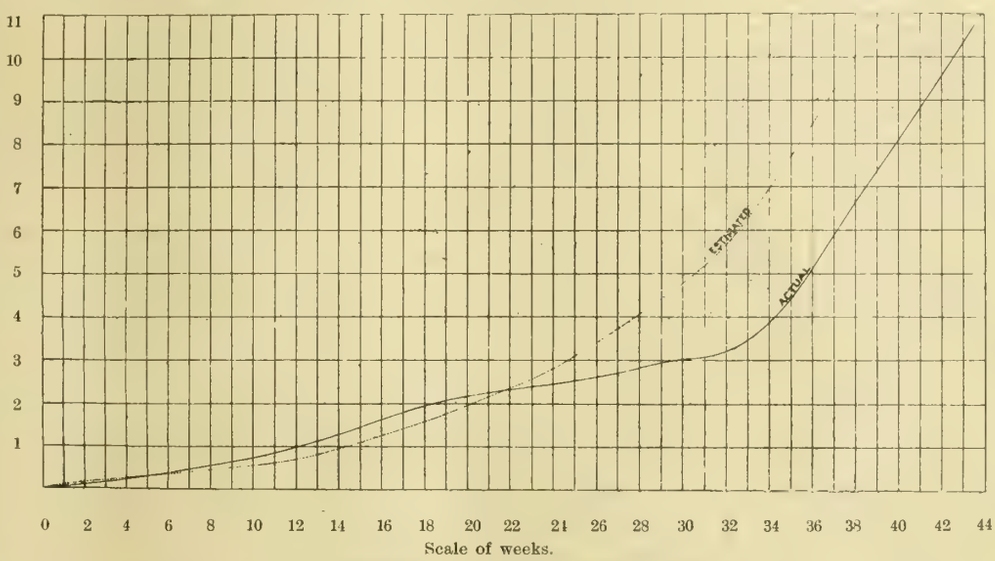


FIG. 8.—COST PROGRESS CURVE. STEEL WAGES.

The ordinary book-keeping systems have been criticised, overhauled, and improved until there is probably little to be done in further improvements except perhaps in minor details, but the full development of a good net cost system and the establishment of a close connection between the net cost estimating and constructive departments on the lines indicated above deserves the careful attention of all those who are concerned with factory organisation. The best results are likely to be obtained by the closest possible combination between accountants and engineers, for if either is eliminated some essential element of success is sure to be forgotten.

No discussion on the financial organisation of factories, so far as it affects internal work, should disregard the great and vexed question of establishment charges. The closeness of the estimating and the accuracy of the net cost systems are indicated very clearly by the number of items placed under the head of indirect charges. When there are few, the work is well sub-divided and a good measure of accuracy may be counted upon; when there are many, the opposite may be confidently expected. The basis on which indirect charges should be calculated in costing and estimating has been argued at considerable length by manufacturers, and it has been held that some percentage should be taken of the total cost of labour and material.

Let us imagine two sister ships, one plated with ordinary steel and the other with galvanised steel. The actual labour cost and works expenditure account to be covered by establishment charges would probably not show any very large difference between them, but a percentage on the sum of labour and material costs would show something rather substantial in favour of the second vessel. This argument in some form or another seems to show that the only correct basis on which charges should be calculated for net cost and estimating purposes is the labour cost. On the other hand, where contracts are placed on a time and material basis, it is probably a benefit to the purchasers to fix charges on material and labour, as this gives them an inducement to check extravagance in the choice of material.

The sub-division of charges is a question which probably never will be finally settled, for conditions in engineering works and shipyards are constantly changing, and though elasticity is claimed as an essential of a good costing system, this admirable quality must sometimes fail under new developments and then changes have to be made. In engineering works where a large amount of the work is done on machine tools, it is probably advisable to charge all such capital cost items under a special heading, and provide for them by fixing a rate for each machine which is added to the cost of all the work which it produces.

The extent to which this should be carried, how far shop charges should be kept separate from establishment charges proper, whether it is advisable to separate shop and departmental from distribution and general charges, and many questions of this kind can only be decided by the exigencies of the particular business which is in question, but it seems to the writer that the greatest accuracy may be expected where the items under direct charges are many, and those under indirect charges few, and that the best facilities for scrutiny by the management will be provided if sub-division is carefully made on this line.

The cost of estimating and tendering is an item which should be carefully kept if only as a record of the unproductive work, and a guide as to how and where it has been apportioned, for this brings under review the idiosyncrasies of customers in regard to the demands they make on the estimating staff, compared with the value of the orders given, and may form an important factor in deciding policy. The perfect cost system should be capable of showing at a glance the cost of work as it proceeds, but, unfortunately, the system has yet to be devised. It may, however, be taken, that in most factories, shipyards, or engine works, some little signals can be set up which will indicate to the management symptoms of the financial health of the place which will be serviceable.

Weekly returns of material and wages showing how they are apportioned; weekly output of various trades, machine time worked, and many similar data can be easily collected and applied as best suits the particular trade or the requirements of the management, but in this, as in all detail costing arrangements, the exercise of very wise discretion is required in deciding the extent to which details shall be carried. The case of Woolwich Arsenal has been quoted above, and it is easy to imagine that there may be many others. The output of shipyards can, to some extent, be shown by the number of rivets worked, provided proper corrections can be made for difficult work, bad weather, holidays, or other causes which reduce output, and a comparison between these results and say the charges, requirements of the yard or the volume of

work in hand is often a useful guide as to general progress. A characteristic curve (Fig. 9) is given to illustrate this. No doubt, numerous checks such as this have been devised and are in use in most of the manufacturing establishments where the financial organisation has been studied, for they can easily be worked out by collaboration between the management and the accountants' department. This collaboration should always exist and be encouraged, for by no other means can the financial aspect of the work be shown quickly and accurately; without this information it is impossible for the management to judge whether or not the whole organisation is in phase, to apply the necessary corrections if required; and at the same time to exercise such supervision over the estimate as is essential in preparing tenders.

*So far only the internal finance of factories has been considered, but a very large and important question is opened when the finance connected with the disposal of the product comes under discussion, for it points to the desirability of reconstituting or perhaps creating financial institutions, banks, or trading companies which shall help to build up our trade abroad. If this country is to obtain the trade benefits which are not only desirable but absolutely essential to her healthy existence, the time seems to have arrived when the whole machinery required for obtaining and fulfilling foreign orders should, where it does not at present exist, be set up at once, and where it does exist, should be put into the best possible working order.

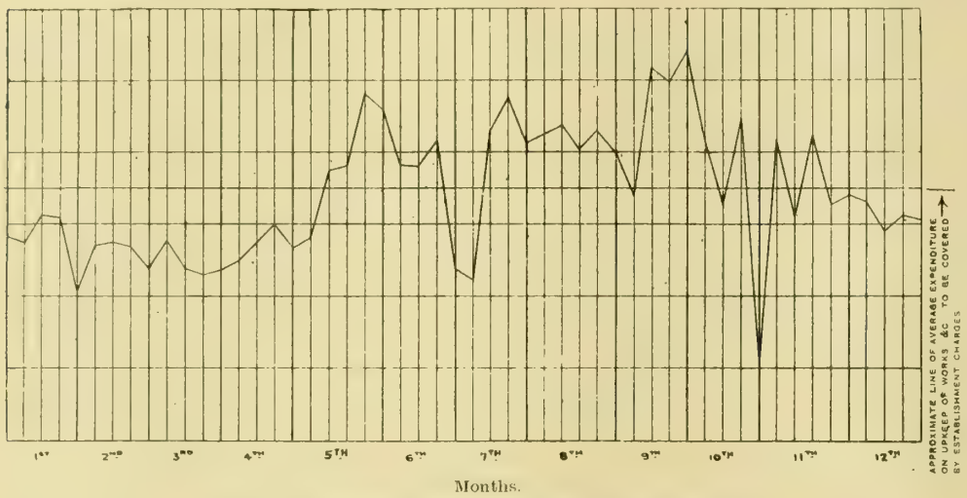


FIG. 9.—CHARACTERISTIC CURVE OF 12 MONTHS' RIVETING OUTPUT.

In the writer's view the first great necessity is a banking company (subsidised by the Government if need be, or relying on its own resources if these are sufficiently strong) which shall finance manufacturers who find it necessary to grant long credit terms to foreign customers. German success in securing such trade is largely due to this, and her example will no doubt be followed by neutral countries who are better equipped with capital than ever before, have developed manufactures and require markets. American institutions of this kind are already in existence, and have no doubt done much to foster trade during the war. The system may be considered too speculative to conform with the strict principles of British banking, but it should not be impossible to devise means for relieving the ordinary depositors of the trade risks by underwriting as is done—the writer understands—in Germany by associations of insurance companies who guarantee the purchasers' obligations at a fixed rate of interest. An institution of this kind has been established in England for the furtherance of trade with Italy. This has a capital of £1,000,000, and for the next ten years a subsidy of £50,000, but for the development of trade with, for instance, Russia, a bank of this kind would have to be on a much larger scale. A capital of £10,000,000 as a foundation is suggested by one Russian writer (M. Alexander Wilner, "Times Russian Supplement," July 29th, 1916), and this may serve as some guide as to the order of magnitude of the figures which would probably be involved.

The financing of trade would not be the only function of such a bank, it would also arrange to collect by means of trade and banking connections, all such information as is essential in building up a trade organisation. This would be distributed amongst the potential purchasers and traders as found desirable, and thus lay the foundations of business relations which only require satisfactory productions from the factories to develop them into permanent connections. It will probably be agreed by those who have had business negotiations with Russia and other foreign countries that there is nothing difficult about such a scheme, and provided that it can be linked up with the existing banking facilities in all the important trade centres it might quickly become a trade organisation of enormous value to our industrial community.

The organisation should probably be a combination of banks, merchants, and manufacturers, supported by the Government financially if necessary and through international channels whenever and wherever required, but should not be under Government control. No small private companies should be allowed to enjoy similar facilities at all events until after the current of trade with this country is firmly established, as it is necessary that all our forces of this kind should be concentrated and directed towards the one object in their fullest strength and rapidity; conditions which it is impossible to obtain if competition between small forces is permitted.

The details of the work to be carried out by such an institution are numerous and comprise: (*a*) Translation into the particular language and numeral system of communications between buyers and sellers, in fact, all the literature of the trade. (*b*) The dissemination in the proper direction of all such information as may spread full knowledge of the productions of firms involved. (*c*) The collection of information regarding the requirements and standing of possible purchasers; and (*d*) the training and development of suitable men to act as pioneers of British trade, who shall have sufficient technical knowledge to appreciate possibilities, understand and overcome difficulties, and sufficient standing to be entrusted with powers to negotiate contracts if necessary.

This side of trade, essential though it is, has never yet been sufficiently cultivated by this country, and it is to be hoped that some stimulus may be given now by the discussion on these three papers to the combination and movement of all the forces necessary to bring into existence and to support such a trading company as has been roughly described. Unless some such steps are taken it is to be feared that this country will lose the best opportunity she has ever had of developing the Colonial markets and forming close business relations with our Allies, which should develop into a large and mutually advantageous trade. This question may perhaps be considered to be outside the scope of a paper on the financial organisation of factories, but as the disposal of the product is essential to the factory, it seems to the writer that in this crisis of our trade nothing should be left undone which may induce intelligent opinion to consider such a line of action as may most benefit our industries; it is to be hoped, therefore, that in the discussion the institution may hear from men who can speak with authority on all the details of financial organisation, and that some definite direction may be given, along which combined action, with, if necessary, Government support, can be taken, which shall exercise a real effect in promoting our foreign trade.

* This part of the paper was written at the end of July; the writer thinks it well to note this date, as the report of Lord Farringdon's Committee, which appeared on September 22nd, bears so close a resemblance to the rough ideas which he has outlined.

Boiler Explosions.—The formal investigation ordered by the Board of Trade to be held in connection with the boiler explosion at Paisley is fixed for hearing in the Court House, Paisley, N.B., on Monday, November 6th, at 11-30 a.m. The formal investigation ordered by the Board of Trade to be held in the case of the boiler explosion at Copperfield Road, Stepney, E., is fixed for hearing in the St. George's Town Hall, Cable Street, Stepney, London, E., on Wednesday, November 15th, at 11 a.m.

INSTITUTION OF MECHANICAL ENGINEERS: PRESIDENTIAL ADDRESS.

BY W. CAWTHORNE UNWIN, LL.D., F.R.S.

It has not been usual for the president to make a formal address at the opening of the session in his second year of office. I do not know whether this is due to consideration for the president or is a measure of relief to members. In normal times I should not have departed from precedent. But with your acquiescence I should like to make a short statement, partly to explain the position of the institution, partly to expand a point in my address a year ago. I recognise that a statement by the president is not discussed, and that his views, if erroneous, do not commit the institution. He is the more bound to be careful and moderate.

The conditions of the time have unavoidably restricted some of the activities of the institution. We have placed our building at the disposal of the Government, and there is no immediate prospect of regaining the use of it. Happily, through the kindness of the Institution of Civil Engineers, who permit to us the use of their meeting hall and library, the inconvenience to our members has been much diminished. It is a difficulty that six members of the office staff of the institution have been called up for active service, and it is inconvenient to the secretary to carry on the considerable business of the office with untrained assistants. Nevertheless, so far the meetings have been held regularly; several provincial meetings have been held, and the "Journal" has been issued as usual. The Council decided that it was impracticable to hold the summer meeting, the conversazione, or the annual dinner when so many members were absorbed in war work. In this they have taken the same course as other scientific societies.

The number of candidates for election does not seem to have been much affected by the war. Taking the first six months of the year, the number elected was 129 in 1914, 100 in 1915, and 112 this year. As would be expected, somewhat fewer candidates have presented themselves for examination. Nearly 900 members of the institution are known to be on active service, and many others are engaged on munition or other war work. Unhappily, so far as is known, 29 have died on service and 30 or probably more have been wounded. Our sincere sympathy goes out to their friends in their bereavement. They have died in a great cause and in the service of the country in its extreme need. So far as we know, 15 members on active service have been decorated and eight mentioned in dispatches.

It would not be right to pass over, without an expression of our deep sorrow, the deaths of Sir H. Frederick Donaldson, K.C.B., a past-president, and of Mr. Leslie S. Robertson, so long the secretary of the Engineering Standards Committee. They were lost in the disaster to H.M.S. "Hampshire," when accompanying Lord Kitchener on a mission to Russia.

There has been rather more difficulty than usual in obtaining papers for the present session, but I trust we may have no mishap. We have tried to obtain a paper dealing with the work of women in munition factories, but so far have not succeeded. It is believed that their services have been invaluable, and that for such work as they can undertake they are little inferior to male workers, either as regards quantity or quality. We hope to have one or more papers on the special machinery for shell manufacture; also shortly a report from the Hardness Tests Research Committee.

In my address a year ago I urged that the rapid economic progress of Germany since the war of 1870, and chiefly in the last 25 years, should be very carefully considered. Relatively, Germany has progressed in many industries much faster than we have. If we are to recover our position, as I believe we may do in the new conditions after the war, it is necessary we should study accurately the facts and causes of German expansion. No doubt that expansion has been too rapid to be healthy, and seems to have induced a feverish sense of insecurity, so that under whatever inspiration the war began, it is certain that commercial and industrial necessities and ambitions had a large place. As an example, which appeared to me remarkable, though it is only one of several, I referred to the iron and steel industry, in which not so long ago we were supreme, but in which we now hold third place, and not a good one at that.

In a quarter of a century the production of pig iron in Germany has trebled and that of steel has sextupled. In 1913 Germany produced 18 million tons of steel, and we produced 7 million tons. It is quite true that nations must depend on each other for products which each is best able to manufacture, but this hardly applies to the iron and steel industry. We have not been wanting in metallurgical knowledge nor obviously worse off in natural resources. Hence the rapid increase and present magnitude of the German production of iron and steel seems to me to have a lesson for us. German trade is conducted thoroughly and unscrupulously as a warfare, and it may well be that the fostering of the iron and steel industry is to be reckoned amongst the preparations for war, for without a great capacity for iron and steel production the present war could not be prosecuted. It is impossible to ignore the ambition frankly stated by Dr. Ostwald, the distinguished Leipzig professor, that Germany "having become the military centre of Europe, it was necessary for her to become the industrial centre also."

In a very interesting address to the Royal Society of Arts, Dr. Dugald Clerk made a protest against the tendency to contrast unfavourably British achievements in science and industry compared with those of Germany. With most of this address I heartily agree, and in any case I should differ from Dr. Dugald Clerk with reluctance and even with some trepidation. Many years ago, Walter Bagehot wrote, "We English are always grumbling at ourselves. But, after all, England is a success in the world; her career has had many faults but it has been a fine and winning career on the whole."

Dr. Dugald Clerk quoted my reference to the iron and steel industry, and replied to it that "it is misleading to cite the relative production of iron and steel as proving either the prosperity of Germany or the decadence of England." As an explanation of the difference in this matter of England and Germany, Dr. Dugald Clerk says that "the United Kingdom has a total of 23,000 miles of railway and Germany has 38,000 miles," and that "it would be extraordinary if a capable and industrious nation, such as the Germans are, could not succeed in making most of the steel required for their own use." But he had forgotten that in India there are 33,000 miles of railway, almost as many as in Germany, mainly built and maintained by the use of English steel, and railways in other Colonies naturally supplied from this country. The railway mileage test does not seem to explain the large German production of steel.

Dr. Dugald Clerk says also that the greater part of German steel is used at home. But how far is that true? In 1912 Germany exported a million tons of pig iron and 4 million tons of steel partly manufactured.* In 1913 we imported from Germany iron and steel to the value of £7,500,000, and in addition machinery to the value of £2,300,000.† Take a single article, railway rails. Between 1908 and 1912, only four years, the export of rails from the United Kingdom decreased 10 per cent., that from Germany increased 16 per cent., and that from the United States 22 per cent. In 1912 both Germany and the United States exported more rails than we did. Now the iron and steel industry is a basic industry, the prosperity of it affects almost all other industries. We might get on without a dye industry, but the steel industry is vital.

The impulse to the development of the German iron and steel trade came from the acquisition in 1871 of part of Lorraine, containing 1,800 million tons of minette iron ore, followed by the discovery, in 1877, by Thomas and Gilchrist, of the basic process. Probably Germany expected as one result of the war to annex the still larger iron deposits in the part of France now occupied by her armies. Mr. Ellis Barker has stated that the attack on Verdun was probably due to the wish to deprive France of her iron ore. It is probably true that steel is produced in Germany more cheaply than here. The works are on a very great scale and under the most able commercial and scientific management. German steel is almost exclusively made by the basic process. British steel is made chiefly by the acid process, which requires purer ore,

* Board of Trade. Iron and Steel, 1912.

† Sir L. G. Chiozza Money.

and in fact a large part of our production is from imported ore. I believe we could produce more basic steel, and it is worth consideration whether a prejudice against basic steel justified in early days is now reasonable.

An influence which in the opinion of continental economists has been powerful in the development of German trade is the system of Kartells, which has been formed since the passing of rigidly protective legislation in 1879. One of them, the Steel Union, embraces 31 firms with an annual output of 12 million tons. Based on mutual consent, it controls the selling price of steel in each district, the area within which each selling agency may supply, the total annual output of each steel works, and the allocation among makers of the profits. It was ostensibly the object of this combination to reduce cost of production by regulating output and abolishing competition between firms in the syndicate. No doubt a less openly confessed object was to acquire selling monopolies and impose its own price on consumers.

It is alleged that the Steel Union systematically resorts to dumping. In normal trade the price increased with the distance from the centre of production, being loaded with transport and other charges. In dumping the reverse is the case, out of profits made in a protected home market, bounties are given on exports to vanquish competition. For instance, from figures given by M. Milliond, girders and rolled bars sold in Germany at M.130 were sold in England and South America at M.103 to M.110, and in Italy, where it was desired to hamper a struggling industry, at M.75. Sir Robert Hadfield has stated that before the war the export bounty granted by the Steel Union amounted to M.15 per ton. The sale at a low price of an accidental surplus due to over-production is one thing; deliberate over-production in order to defeat competition abroad by dumping is another. Competent observers like M. Milliond believe that that has been the policy of the Steel Union.

Perhaps there is nothing illegal or which contravenes ordinary trade morality in a system of dumping. The Commissioner sent by "The Times" in 1901 to report on "American Competition" states that the American manufacturers openly avowed the intention to keep up prices by stinting the home market in order to force the export trade by cutting prices in foreign countries. Possibly the importance of dumping may have been overrated. Continental economists do not seem to think so. But I do not believe that any nation subjected to systematic dumping will permanently submit to strangulation by an unfair trade method. It is not for me to suggest a remedy. No doubt one can be found, and personally I hope it may not interfere with our custom of unrestricted trade.

To adopt a Kartell system with the protection which is its basis in Germany, would be contrary to our ideas and traditions. But dumping is not an essential part of association in trade. We may recognise that as Naumann says, in Mittel-Europa, "combination means the elimination of wasteful competition, economy of large production and gains from expert buying and selling on a large scale." It is a matter for consideration whether our trade methods have not been too individualistic. There would seem to be advantages in co-operation of firms, not merely to control labour, but in introducing methods of workshop organisation, in pooling commercial and technical knowledge, in uniting in scientific investigations, and in establishing competent agencies in foreign countries. The Engineering Standards Committee is an example of advantages obtained by consultation and compromise without interference with individual freedom, and standardisation of production is likely to be much extended after the war. Mr. Asquith said, "I lay particular emphasis on two tendencies. The first is the development of trade associations for common action at home and abroad, raising the average standard of production. The second is the recognition of the leeway we have to make up as regards scientific research and its application to technical and industrial purposes."

In August, 1914, the Navy was ready but in other respects we were unprepared for the war which was forced on us. But the way in which our characteristic unpreparedness, slackness, and inertia have been overcome and organisation created is extraordinary. It is an engineers' war, and mechanical engineers can realise the task involved in their department. Four thousand factories are under Government control, and the private workshops have been organised under local committees and adapted to unaccustomed work of great precision. In Mr. Asquith's words, "the history of the war in the industrial sphere at home has been a history of grave and threatening difficulties, courageously faced and successfully overcome." In spite of the withdrawal of men for the front and the employment of a million and a half of men and nearly half a million women on munition and war work, ordinary activities have been kept going without serious embarrassment. But when the war is over there lies ahead another strenuous time. There will be the cessation of war expenditure, the return of the men at the front with physical and mental capacity enlarged by the experience and discipline of service, and the disposal of the women who, in munition factories and elsewhere, have been replacing men and earning unaccustomed wages. Still, there is no reason for pessimism. Our productive output has been enormously increased under war stress, and may be maintained in peace. There has been the creation of very large new engineering factories, older factories have been overhauled and equipped with new high-class tools. Manufacturers have co-operated in a way unknown before, and workshop methods and organisations have been improved. Industry has been modernised and invigorated.

Certainly relations between employers and employed have been unsatisfactory in the past. There are signs that the admirable co-operation which has been exhibited during the war has produced a better feeling. We may hope that with some increase in the rewards and improvements in the condition of workmen deliberate restriction of output may be abolished. Adopted partly from false economic ideas, partly from natural anxiety as to wages and status as craftsmen, it has been, as Mr. Arthur Chamberlain says, effective, but at a terrible cost in loss of production.

THE GRINDING OF HIGH-SPEED STEELS.

SOME interesting information respecting the grinding of high-speed steel cutting tools is given in an article by Mr. C. E. Gillett in a recent issue of "Grits and Grinds," published by the Norton Company, of Worcester, Mass., U.S.A., which we reproduce in part as follows:—

That the heat generated in grinding does not affect the temper of high-speed steel is a rather prevalent idea. This opinion is derived from the fact that cutting tools made of this material will stand up and maintain their cutting edge under a red heat which would render a carbon steel tool useless. The fact is, high-speed steels can be ruined as easily by grinding as the ordinary carbon tool steels.

High speed and self-hardening steels may contain tungsten, chromium, manganese, molybdenum, titanium, or other elements, combined with from 0·40 to 2·20 per cent. carbon. Tungsten influences the rate of hardening and the depth to which the hardening effect penetrates below the surface. It also resists the formation of a large crystalline structure, and hence produces a keen and durable cutting edge. Chromium produces a very hard steel with a high elastic limit. The combination of tungsten and chromium is responsible for the remarkable properties of the modern high-speed steels. Manganese is used to toughen the steel without reducing the hardness. Molybdenum has properties very similar to tungsten, 1 per cent. of the former being equivalent to 2 per cent. of the latter. Steels treated with titanium show greater resistance to abrasion and heat up more slowly from friction than steel not similarly treated.

Many tools which are supposed to have been spoiled by grinding are not properly heat-treated. If the tools, when carefully reground, are still in poor condition, the chances are that the heat treatment is at fault. In grinding high-speed steels it is necessary to observe numerous precautions which are not necessary with the carbon steels. Lighter cuts, slower speeds and traverses are usually necessary, although cases have been known in cylindrical grinding where it was necessary to use the very high work speed of 260 surface feet per minute in order to avoid burning and cutting edges of an inserted tooth mill. This fast work speed was probably necessary because the wheel in use was too hard. The greatly increased work speed resulted in an increase in the grain depth of cut, which in turn caused the wheel to act softer. This, however, is an unusual case. In most instances a low work speed is preferable.

Undoubtedly the most discussed point in the grinding of high-speed steels is with respect to the use of water. At first all of these steels were ground dry. Later some more courageous than the rest, advocated grinding wet. The superintendent of one of the largest small-tool manufacturing concerns recently stated that it was a crime to grind high-speed steels dry. In wet grinding, a liberal supply of water must be available. The tools being ground should be flooded with water. A Norton special service man was called in recently by a firm manufacturing a machine for grinding a special type of high-speed steel tools. A saucer wheel, mounted on a vertical spindle was being used to grind a broad, flat surface. A $\frac{3}{8}$in. gas pipe and rubber tube directed the water on to the back of the wheel, whence it flew off by centrifugal force without striking the work. Naturally considerable trouble was experienced on this operation. The special service man recommended that more water be directed between the wheel and the work. This was done and the results obtained were astonishing. A second connection was made whereby water could be directed on to the work from both sides. From a near failure the machine was converted into a practical commercial proposition.

It is necessary, in many cases, to grind dry, and if care is not taken, skin softening will result. Skin softening is the softening of a very thin layer on the surface of the tool being ground. It may be detected by passing a file across the suspected section. The file will take hold of a softened portion of the surface. However, a second pass of the file in the same place will usually show that the soft skin has been removed and that the hard stock has been reached. Lathe tools, drills, and cutters burned in grinding, or skin softened, generally can be redeemed by grinding off $\frac{1}{64}$in. to $\frac{1}{32}$in. of the burned section. In dry grinding formed tools made of Styrian steel, hardened and tempered, were used in a universal machine. It was noticed that burning always resulted if grinding was from the body to the point of the tool. However, in grinding from the point to the body, this trouble was eliminated. In the latter case, the heat is driven ahead of the wheel on to the body of the tool, which has a greater capacity for holding the heat generated.

Checks and cracks are very easily obtained on some types of high-speed steels, if great care is not observed. This is possible with both wet and dry grinding, but more prevalent with dry grinding. An easy way to produce checked tools is to grind dry and occasionally dip the tool into a pail of water. Another method of grinding is to heat the high-speed tools to a temperature at which they are used under normal working conditions. Such grinding necessarily must be done dry.

Wheel speeds are very important. It is a well-known fact that wheels will act harder at higher speeds. For general grinding, most abrasive wheel manufacturers recommend a wheel speed of 5,000 surface feet per minute. At the suggestion of a Norton special service man, one concern manufacturing high-speed steel tools reduced the wheel speed on a certain operation to from 4,500 to 4,700 surface feet per minute. At once several of the difficulties experienced were eliminated. As a result every grinding machine of a cylindrical, universal, or special type was changed over to a lower wheel speed. Production was increased 25 per cent. and the wheel cost was decreased 33 per cent. through the use of slightly harder wheels on the work.

The properties of high-speed steel are such that wheels which will grind without burning or checking are considered too soft, when the comparison is based upon the life of wheels used for grinding carbon steel tools. However, it should not be forgotten that the greatly increased production obtained with high-speed steel tools is due in a large measure to the fact that it is possible to do a greater amount of work without regrinding the tools. A careful investigation of this point by wheel users will show them that the wheel cost per unit of production has decreased.

The artificial aluminous abrasives of special temper, known as No. 38 alundum and No. 26 alundum, make the best wheels for grinding high-speed steels. The wheels must generally be of coarser grit and softer grade than is used for similar work on carbon steel. Coarser softer wheels cut faster and cooler. However, grit of too coarse a size will not leave a good finish on the tool, the cutting edge being rough and irregular. For cylindrical work, finer, harder wheels can be used, but for broad flat surfaces a very much coarser, softer wheel is necessary.

The best results are always obtained when the wheel is running true. Wheels for tool and cutter work should always be dressed with a diamond, care being taken not to use too dull a diamond or to dress the wheel too fine. As soon as the wheel starts to glaze and heat the work, it should be dressed again. Two or three passes of the diamond are sufficient to produce a good free cutting wheel face.

The grinding of high-speed steels commences immediately after the mould has been drawn from the castings. The surface of the billet usually contains seams, cracks, or blister marks. It is necessary to grind out these blemishes prior to rolling the steel into bar form or poor material will result and considerable of the stock may have to be rejected. The action of a seam or crack in high-speed steel is similar to the piping in billets used for steel rails and other heavy shapes. These billets of high-speed steel are ground either on a floor stand, or with a swing frame grinder, according to the weight of the piece. The wheel speeds in general average from 5,000 to 6,000 surface feet per minute.

Practically all grinding of drills, reamers, milling and formed cutters, and similar tools is done wet. Owing to the hardness of many high-speed steels, it is impossible to cut off small pieces of stock $\frac{1}{4}$in. to $\frac{3}{4}$in. square for lathe and planer tools in the usual way. Thin wheels, produced by the Vulcanite process, up to 12in. $\frac{3}{32}$in. are in great demand for cutting off work. A good average for cutting off $\frac{5}{8}$in. square stock with a vulcanite wheel is 15 seconds per cut; for $\frac{1}{2}$in. and $\frac{3}{4}$in. stock with an elastic wheel, the time is 10 and 20 seconds per cut, respectively.

Many manufacturers are trying to grind high-speed steel and carbon tools under the same conditions and with the same wheels. Naturally this is possible, but such methods cannot secure the greatest efficiency. It is better to have two sets of wheels and to use each for the particular material whereon it is most efficient. The greatest obstacle encountered in this respect is the disinclination of the operators and foremen to be continually changing wheels. In the small shops the time necessary to change wheels would not be a serious factor. In the large shops a little study and conscientious effort can readily effect a grouping of machines and routing of the work which will bring forth the best results in the grinding of both materials, and will effect a saving in the operating costs.

Lloyd's Shipbuilding Returns.—The returns compiled by "Lloyd's Register of Shipping," which only take into account vessels of 100 tons and upwards the construction of which has actually begun, show that there were 469 merchant vessels of 1,789,054 tons gross under construction in the United Kingdom at the close of the quarter ended September 30th, 1916, which is about 249,000 tons more than that which was in hand at the end of the previous quarter, and about 253,000 tons more than the tonnage building twelve months ago. Of the merchant vessels being built in the United Kingdom at the end of September, 406 of 1,442,003 tons are under the inspection of the surveyors of "Lloyd's Register" with a view to classification by that society. In consequence of the war it is not possible at present to publish the usual information regarding the shipbuilding industry throughout the world.

The Society of Engineers.—At the ordinary meeting of the Society of Engineers, to be held at the apartments of the Geological Society, Burlington House, Piccadilly, W., on Monday, December 11th, commencing at 3 p.m., two papers will be presented for discussion, dealing with the sources of minerals and mineral ores required in the engineering industry of the United Kingdom. The first paper will be presented by Prof. W. G. Fearnsides, M.A., Sorby Professor of Geology at the University of Sheffield, and will deal with the minerals required by the iron and steel industries. The second paper will be presented by Prof. C. G. Cullis, D.Sc., M.Inst.M.M., Professor of Economic Mineralogy at the Imperial College of Science, and will deal with non-ferrous ores. As the subject for discussion is of exceptional interest at the present time, and a large number of eminent engineers and metallurgists will be invited to attend, the Council have decided to throw the meeting open to the public by tickets, which may be obtained (gratis) on application to the Secretary, 17, Victoria Street, S.W.

FRICTION CLUTCHES.*

BY WILLIAM G. GASS, M I.M.E.

It is a little difficult to know where to commence the treatment of a subject like a friction clutch, which is not a machine in itself but only a part of machinery, and of which there is so great a variety, so many makers, and such extended use. The author does not therefore propose to deal with any one type, but to review the general types into which they may be classified, to refer to their common points and detail, and as far as possible their weaknesses and faults; not with the idea of extolling one type against another, but by bringing their faults to view to help towards their removal, for it is only by consideration of weak points that we can strengthen them. It may be taken as an axiom that, though one type of clutch may have advantages over another, there is not any perfect clutch, some types answering better than others for different classes of work; this is a great point to bear in mind when arranging clutch drives. We may commence by defining a clutch as a mechanical device by which rotary motion is transmitted from a first-motion shaft to another or second-motion shaft, which may be either in the same straight line or parallel with it. Clutches are divided into a number of distinct types: (1) Claw couplings, (2) friction cones, (3) internal segment and band clutches, (4) external segment and band clutches, (5) plate clutches, (6) brush clutches, (7) magnetic clutches, (8) automatic clutches.

Claw Couplings.—Claw couplings cannot be generally classified as friction clutches, but they can be and are combined with a friction slipping device by which some of the shock is absorbed when thrown into gear with the prime mover when rotating. Without any friction device they are very useful on machines where the load is not very great, as they have all the advantages of giving a drive with no chance of slip. Where used for transmitting heavy loads or at high speeds they should only be put in gear when the machine or shafting is stopped. They are also very difficult to release when transmitting heavy loads.

Friction Cones.—These are the simplest form of friction clutch, and for some purposes the best, because simple in construction; if properly made they drive very well; they have the serious defect, for general use, of requiring to be held up with a constant pressure, which absorbs power and causes wear on the setting-up gear and the bearings taking the thrust of the setting-up gear. A portion of the constant thrust can be eliminated by making the angle of the internal portion sufficiently small, but this makes the cone liable to stick, and it is not infrequent, when large cones are so made, to have to hammer the outside of the cone to make the two portions come apart.

If, on the other hand, the cone angle is too large, the pressure required to keep the two parts in gear is so great that it is very difficult to transmit the power. Generally, these large cones are used for driving machinery in bleachworks and similar places, and are useful where there is a good deal of wet about. They are usually made of cast iron, the inner part sliding on the shaft on float keys, the outer part running loose on the shaft. They have been tried as double cones with internal and external bearing surfaces, but there is nothing to justify such an arrangement. If covered with some frictional substance such as leather, or any of the numerous frictional materials made for the purpose, the driving power is increased.

In motor-cars the cone has proved a most valuable type, as the usual conditions are reversed, and it is as a constant driver that its value comes in. The arrangement in motor-cars is such that there is no end thrust except when it is not transmitting power, and is, therefore, working under the best conditions.

Internal Segment or Band Clutches.—These are divided into two distinct types—those in which the internal segment is in two or more sections, which are forced apart, by means of screws usually; and those in which the internal segment is cast all in one piece, so arranged that the driving portion is expanded against the spring of the metal. This type is made in two forms; in one case the segment is sprung apart at two points, and the other in one place only. Similar forms are made with hinged portions. In the loose segment type, the segments are carried on the arms of a turned internal piece, usually keyed on to the shaft as driver, but in other cases sliding in grooves made to receive them in the driven portion.

External Segment or Band Clutches.—The external segment or band clutch is made in quite as many forms as the internal-band type, but is more generally used for the smaller powers. The segments are in two, three, or four pieces, forced on to a central drum, and carried in much the same way as the previous type. A single band, similar to a brake drum strap gripping on a central drum and set up by a wedge, is one form; another has two bands and is set up from opposite sides. Another takes the form of a spring coil which tightens up by tension and friction, and is, in fact, an external cone clutch with a flexible rim. It is not usual to consider a fast and loose pulley drive as a clutch, but it comes under this head, the belt being the external friction band.

Plate Clutches.—A plate clutch is distinct from any of the other forms, as the gripping surface is between two or more flat plates pressed together, one plate being attached to the driver and the other to the driven alternately. These are forced together by levers through a toggle joint. Another form of this type has the plates of stamped steel formed into a kind of double cone, which is supposed to give it extra gripping powers.

Brush Clutches.—These utilise the resistance of a great number of projecting wires which, when the two portions are pushed together, interlock, and give the necessary power of driving.

Magnetic Clutch.—Magnetic clutches have generally two flat faces, though conical surfaces have been used, which are pulled together by the power developed in an electro-magnet formed in one half the clutch.

Automatic Clutch.—Automatic clutches depend on centrifugal action to keep the surfaces in contact, and are used in connection with electric motors, being designed usually to come into operation at certain desired speeds.

The foregoing brief summary of the different types makes it evident that their number is very great, and that it would take more than the space available to describe them in anything approaching detail. They, however, all possess points and faults in common, and it is these which it is proposed to consider as well as their other features.

Driving Surfaces.—These are for the most part metal on metal, usually cast iron on cast iron. In cones, and in internal segment clutches, in the old days they used to be covered with copper plates riveted on by copper rivets. Many of the oldtime millwrights, particularly in bleach and similar works, would not have anything else, but there are not many made so at the present time. Copper covering did not materially increase the driving power, but it was generally believed to do so. If the clutch were heavily loaded there was a tendency for the copper to creep and shear the rivets. Examination of the surface of the copper after long work showed the surface was embedded with fine particles of iron from the outer part of the cone or clutch, and it became hard and glazed, the pieces of embedded iron being hard and exceedingly sharp.

There are several kinds of friction material now made which are recommended for clutches. These, no doubt, are of advantage for brakes, but there are difficulties in the way of using them for clutches. In most cases rivets have to be depended on, and these are apt to give way. The material is liable to glaze, particularly where the clutch goes in and out many times. Wooden blocks as driving surfaces act very well if the load is not excessive, but if over-taxed they char on the surface and give way. Where steel is used it should not be used on cast iron unless its surface is chilled very hard, or, if on steel, on a case-hardened surface. Some of the smaller kinds of clutches use two hardened surfaces, but this must reduce the driving power.

In plate clutches cast iron on cast iron is, in the author's opinion, best, mild steel on cast iron being a failure. One clutch uses a double cone arrangement in which the pressure is on the inside and the outside, and steel plates are used throughout. A great deal is claimed for this, and it is satisfactory

* Paper read before the Manchester Association of Engineers, October 28th, 1916.

as long as it is attended to and not overloaded. In motor cars leather faced cone clutches are in the majority, and the results justify their popularity; they have to work so much as a slipping clutch that metal to metal surfaces have not proved satisfactory unless lubricated. In these the coefficient of friction is, of course, higher than metal to metal. In magnetic clutches fibre on iron is usual, and they are said to give good results.

The trouble of driving surfaces is that they wear away, and this wearing is greater or less as the clutch slips or not. It is obvious that faces of metal cannot slip on one another under pressure without wearing away, and the examination of surfaces which have been in use shows the way in which the loss occurs. The surfaces generally being dry, a small portion of metal gets embedded into whichever of the surfaces is the softer, and acts as a kind of plough into the other. It is not necessarily the softer of the two which gives way, but often the harder. This does not sound quite reasonable, but it is a fact. If you take a lead plate and cover it with particles of emery it will cut away the hardest steel. It is not, of course, the lead plate that cuts, but the emery. The same thing occurs with the clutch; particles of hard material get embedded in the softer and act as the cutting material, but only when the clutch is slipping, so that the wear may be slow or fast depending on whether the driving faces slip much on each other. This explains why clutches put in as slipping clutches are not often very successful.

Clearances.—Clearance is the main difficulty in the general run of clutches and the smallness of it is the cause of a considerable amount of wear when running out of gear. In all cases where the setting up is done by screws, the clearance between the driving part and the driven is a relatively small amount. The cone gives the largest amount of any, and on that score alone is the best. In segment clutches, both inside and outside band clutches, and plate clutches, it is a very serious problem. In the majority of these, where a screw is used, the usual amount of rotation of the screws is about $\frac{1}{8}$ of a revolution, and if screws of say $\frac{1}{4}$in. pitch are used, right and left hand, the movement given to the segment is $\frac{1}{16}$in., *i.e.* $\frac{1}{32}$, on each side, and that represents the clearance when the clutch is out of gear; the actual clearance is less than this owing to the shape of the segments.

Attempts have been made to increase the clearance by racks to rotate the screw through a pinion, but this does not enable the necessary pressure to be put on the screw, and there is consequently a loss in efficiency. In the internal-band clutches, or those of the all metal spring centre type, the movement is less than in the segment type, as the metal will not stand the same amount of movement. In plate clutches it is even less, but these do not need quite so much movement. Usually these are not set up by screws but by the direct thrust from a toggle lever, and when the clearance is divided over a number of plates it is small, and there is consequently some rubbing when the plates are running out of gear, though it does not seem to have an appreciable effect, except at high speeds. In magnetic clutches the clearances must be small or the magnetic efficiency is greatly reduced.

Generally speaking, clutches of all kinds wear away more quickly out of gear than they do in gear, even where they are strong enough to easily cope with the load. Clearances are, therefore, the weak spot in almost all types of clutch, being so small that any wear which occurs in the bushes of the free part of the clutch affects its running, and throws the two portions out of line. This is a serious matter in large clutches, as the ratio of clearance is not in proportion to their diameters, being relatively less with the large size than with the small. Heavy segment clutches running at slow speeds are sometimes supported by external rollers to assist in keeping the outside of the clutch in line. The question of clearance only arises when the clutch is running out of gear.

Setting Up Gear.—In all cases the action of setting up a clutch is the conversion of a sliding movement along the shaft carrying the clutch into a pressure between the clutch surfaces. This may be properly divided into two portions, the first that which is in the clutch itself, and the other that by which the power for operation is applied. In the majority of clutches the locking and concentration of power obtained by the toggle motion is the one mostly adopted, and when once set up has no tendency to slip back. It requires in every case an adjustment by means of a screw which can be set so as to bring the levers in the correct position to give the requisite pressure on the surface.

In most of the internal and external segment and band clutches the adjustment is obtained by moving the main nuts a portion of a revolution and re-locking—the nut having a serrated rim with a locking pin. In plate clutches it is generally done by using the adjustment screw at the point where the pressure to the plates is applied. In others, the forcing of the surfaces in contact is done by a wedge, having at its larger width a parallel portion which takes the end thrust off when the clutch is set up. This wedge is flat in some and circular in others.

With both the toggle joint and the wedge a sliding block is necessary to transmit the power from the stationary lever to the rotating shaft carrying the clutch. In the majority of cases the power is applied to the clutch to set it in gear, but, in others, the power is applied to release it or put it out of gear, the clutch being kept in gear by means of springs. Motor-car clutches are the most common examples of this kind. For general machine driving, where a rapid movement is required for operating the clutch, a lever is usually employed, and if the leverage is sufficient, is quite satisfactory. It enables the power to be applied quickly and as quickly released, and where it is desired to give a slight movement to the machine, and also where the clutch is put in gear and released many times. But where a clutch is in gear for long periods, a screw and quadrant is mostly used. This is as generally fitted to internal-combustion engine drives. It gives an easier starting movement because the pressure can be more gradually applied, but it is much slower both at starting and releasing. Where the lever is used, particularly on a heavy clutch, it requires a strong pull on the part of the attendant to put the clutch in gear. The trouble with all setting up gears is the wear on the pins and lost motion due to clearance in bearings.

Pressure on Working Faces.—This is the crucial point in the efficiency of any clutch and its power to drive, for unless the necessary pressure exists between the frictional faces the clutch cannot transmit its power, and it is here where so much trouble arises in the use of any form of friction clutch. The power of any clutch is of course dependent on the coefficient of friction between the surfaces, and whether they are dry or lubricated, and it is this factor which so materially affects any formulæ for the power of a clutch. There is no difficulty in saying that any clutch should transmit so much power, provided we assume that a certain pressure exists between the surfaces; but there are many very small items which will affect the result, more particularly where the surfaces are metal to metal. The coefficient of friction varies greatly with the state of the surfaces, and after the surfaces become glazed with use it drops very quickly, and the power of the clutch drops in unison.

It is usually considered that if an actual pressure of 50lbs. per square inch can be put on the surfaces it is as much as is desirable for good working conditions; but, if for any reason a less pressure is put on than that required to transmit the power, a clutch will, if it begins to slip, grind itself away quickly, and in the spring-centre type grind away all the available spring in the metal. On looking at the action of the toggle joint it will be seen that the travel of the portions of the clutch being set up is very slight at the end of the movement, when the thrust link of the toggle is approaching the vertical.

Pins are essential, and in spite of all that can be done, will wear so that if a clutch is set up correctly a very small wear on the pins and links of the toggle will rapidly reduce the effective pressure of the faces, even without taking into account the wear on the frictional surfaces. It is, therefore, very necessary to keep a watch on a clutch to see that any wear which may take place is followed up, if the life of a clutch is to be as long as it ought to be.

Where the pressure on the surfaces is due to springs, and these, as they usually are, are in direct thrust, then they will follow up a considerable amount of wear themselves. It appears from this as though springs were the best, but they are only good where conditions are suitable, and this is not generally so for driving machines. The remarks about wear apply equally to wedge setting up surfaces.

The power transmitted is proportional to the speed of rota-

tion, and a clutch which will transmit 10 h.p. at 100 revs. will of course transmit 50 h.p. at 500 revs. The point, therefore, that has to be observed in using a clutch is to see that the pressure necessary to do the driving must always be maintained, if the friction clutch is to do its work satisfactorily, and that allowance must be made for the wear of pins, and other parts, in the adjustment of the setting up gear.

Lubrication.—In clutches, as in everything else, lubrication is of the greatest importance, and more particularly where the clutch is running idle for a considerable part of its time. If the outside portion of the clutch is the driven part, it runs on the shaft and may have to be stationary while the shaft rotates in the clutch bushes, or, if the outside is the driver it has to run loosely on a stationary shaft. This is a fruitful source of trouble with many clutches, and the lubrication of these bushes requires the closest attention, both in design and on the part of the attendant. If the driven portion has to be stationary while the shaft runs in it, there is a tendency for the shaft to wear a groove in the bush, and when this starts it rapidly grows worse, as this part always seems to stop at the same point and be worn oval; while if the driving portion has to run loose on a stationary shaft the bush wears larger and affects the clearances, even sometimes becoming so bad that the friction surfaces never run clear and are always rubbing. When in gear the lubrication is not required, and the oil is liable to be driven out of the bearing surfaces and so be missing when it is wanted.

Many attempts have been made to arrange the lubrication in a satisfactory manner, and as good a way as any is to form a cavity behind the bush, which forms an oil well, and so stores up a supply; but the cavity is liable to become a receptacle for dirt and worn material from the shaft and bearings, and becomes a source of danger instead of benefit. Some makers emphasize the necessity of driving surfaces always running in oil, but a little consideration will show that while up to a certain point this is an advantage, yet it has evils which tend to counterbalance its advantages.

In starting up any friction clutch a certain amount of rubbing takes place, and when two metal surfaces rub on one another fine particles of metal are given off. These, in an enclosed chamber, cannot get away and so become mixed with the lubricant, and form an excellent abrasive which does not increase the life of the parts. This is, of course, obviated by a little care and the occasional cleaning out of the chamber, but as everyone knows this is never done until something happens. Most clutch attendants work on the principle of letting well alone.

Another peculiarity of lubrication in the case of plate clutches is that where the resistance to the idle clutch is not very great, if the oil becomes thick the plates adhere because all the air is driven out between them, and the resistance may not be able to make the clutch stop. Springs between the plates have been tried to get over this, but the results have not been very satisfactory. Excessive lubrication also reduces the driving power materially. Solid grease has much to be said for it for lubrication of clutch bosses, but it is often difficult to get it satisfactorily used.

Application of Clutches.—In considering the question of the best kind or size of clutch to use for any particular purpose it is desirable to know the conditions under which it will have to work. Where the power is being transmitted to a machine from a line shaft to the clutch on a countershaft of a machine, by ropes or a belt, then the outside portion of the clutch is the driver, the rope or belt pulley coming on the boss. In this case an open type internal segment or band clutch is better to use than an enclosed plate clutch, not because one drives better than the other, but for a very simple reason. For this drive with the open type clutch the setting up screws would stop, and can be adjusted when the clutch is out of gear; while in the enclosed clutch the setting up screws would be running all the time and can only be adjusted when the main shaft stops, a matter of great importance if the clutch begins to slip, or requires adjustment for higher power while the shafting is running. But where a range of machines driven off one shaft by gearing is being used, then the enclosed clutch is handier for exactly the same reasons, the setting up screws stop and can be adjusted without stopping the shaft. This should always be seen to, viz., that whatever type of clutch is being used the setting up screws should be able to be adjusted at any time, without having to stop the main drive.

It is desirable to take into account the inertia of the machinery which the clutch has to put in motion. In some machines the starting load is considerably in excess of the working load, and therefore unless sufficient allowance is made in the power of the clutch there will be continued trouble. Take, for example, a heavy calender or mangle in a bleachworks. This, if the set or pressure be on the bowls, may put a starting load of 50 per cent. or more on the running load, and the clutch must be able to overcome the initial load easily, or the clutch wears out quickly. Then, in mangles, say in a croft where there is a great amount of water splashing about, a cone if large enough will give as good results as any type of friction clutch.

There is also the question of the point of control: in any machine the starting lever of the clutch should be in such a position that the attendant can put the clutch in or throw it out of gear from the position he stands in when working the machine; long shafts spring a considerable amount, and should be as short as possible, but a lever and rod will allow for a moderate distance away.

When the point from which a clutch has to be operated is beyond the reach of shafts then the mechanical clutch meets with difficulties, and the magnetic clutch has an opening. But in remote control where the starting operator has not a good view, then there is a possibility of the machine being started when all is not clear and causing accident. This is not likely to occur when the starting operator is near his work and can see what he is doing. There is no difficulty, however, in operating mechanical clutches by compressed air or water power at any distance.

In driving machines that have very little inertia to overcome, like a fan or a dynamo, then it is necessary if a complete stoppage is required that the driven portion of the clutch should be carried on a sleeve, or be a clutch coupling, so that the friction of the bush cannot start the clutch rotating. A sleeve is, in effect, a hollow countershaft through which the main driver passes. As a coupling the friction clutch operates very well, the shafts carrying the driving portion of the clutch being distinct from the driven portion, and when in gear coupling the two shafts together. This is the usual method in coupling to internal-combustion engines in the setting up gear of which the screw is better than the lever. In the driving of a rubber machine for use on plantations, where the operatives are natives and somewhat careless, the friction clutch is very necessary, and it can be quickly thrown out of gear in case of accidents.

The speed at which the clutch is to run is also an important point to consider. In that type of clutch in which the segments are loose the centrifugal action of these segments always tend to force them outwards, making them more difficult to throw out of gear if of the internal type, and more difficult to engage if of the external type. Those in which the centre is all in one piece, and forced out against the spring of the metal, are not affected by centrifugal force to the same extent. Plate type clutches are very little affected by centrifugal action.

The balance of a clutch is also of the greatest importance, as it is rapidly affected by any want of balance, if the speed reaches a point at which it becomes operative. It should, however, be properly balanced for any speed. The cone having no moving parts is undoubtedly the easiest to balance and keep in balance, and would be most used if it were not for its other inherent defects. If the speed is moderate, internal segment clutches, where made of sufficient excess of driving power, have run for periods of over twenty years without renewal, and where they were being constantly thrown in and out of gear. Another point which sometimes affects the use of clutches is the overall space required, which is more than that required by fast and loose pulleys. This is not always of moment, but there very often arise positions where it is important.

In the consideration of clutches as against fast and loose pulleys the question of cost should be looked into. That a belt used over fast and loose pulleys will wear away much faster than one which operates through a clutch is well known, but a clutch is more costly than pulleys, and we have to decide which will be the better. A clutch enables drives to be made by ropes or chains, which would be impracticable without the use of a clutch. Most toolmakers in the States use clutches on their countershafts, while English makers generally prefer

fast and loose pulleys. The author has, in his own works, both sorts running, and although the clutch operates more quickly than fast and loose pulleys, the men do not at all agree as to which they like best. The clutch takes on the whole more power to operate.

Clutches require upkeep like any other machine, and whether this cost is high or low depends on whether the margin of power is sufficient or not. If there is a good margin there will be no trouble; if you have only just enough or just under, then trouble is your constant companion. People who buy clutches without considering the circumstances, or are determined solely by the price often regret their choice, as in a good many lists the powers of the clutches are not understated, but designed to give a very favourable and even rosy hue to the figures.

Something can be said for the simplicity of magnetic clutches and freedom from mechanical movement, but you have to set against these the contacts, switches, cables, and other connections; anybody who has used these and handed them over to the care of some men know that they can equal anything in the way of pins and levers for trouble; also, the constant expense, without taking into account the initial cost, that accrues from the use of magnetic clutches is of moment—for instance, a charge of only ½d. per hour for current is to be looked at, at the end of a year, and is the interest on the price of a very large clutch.

A mechanical setting up gear takes nothing when set up, or, at least, only a small amount for wear and tear. Clutches should be depreciated at a greater rate than ordinary machine tools; they are often difficult to get at, and get attention only when they won't work.

The ideal friction clutch should be a combination of a friction drive and a positive drive. That is, a friction arrangement should be used for starting up, when that is in gear a positive drive should come in operation by which all driving is taken off the frictional portion. The clutch, however, should be able to be thrown out of gear with the same ease that a friction drive can be, and should have all running parts with ample clearance when running out of gear. A little consideration will show that while it may not be impossible, it will be very difficult to attain for this reason. When the positive portion of the drive is thrown into gear, it will be this portion that will be doing the work, and when that is so, to throw this part out of gear creates the same difficulty that there is with a claw coupling, that is, the difficulty of quickly releasing it while under the pressure of the drive. Also it should always be in perfect balance, no projecting parts, lubricated so as not to give trouble, and free from complications.

Some years ago a clutch was put on the market which was a combination of a friction and positive drive, but the author has not heard of it for some time, and supposes that the difficulty with the release would be the probable cause of the trouble. The use of separate electric motors to each machine undoubtedly will affect the use of clutches, but even these are as capable of giving trouble as a clutch.

In order that the discussion on the paper may run in channels which, in the author's opinion, may lead to practical results, he suggests that the following points might receive the most attention: (1) The best means of lubrication of the clutch, so that wear on the bushes may be kept down to the lowest point. (2) The question as to whether results justify the extra expenditure on clutches without a moving belt as against fast and loose pulleys with a moving belt. (3) What is the reason that British tool makers stick to the fast and loose pulleys as against the use of clutches on their machine countershafts? (4) Does the magnetic clutch, as far as experience goes, justify the expenditure on current necessary to keep it in action? (5) Are friction surfaces of the woven or similar type better than metal to metal surfaces?

The foregoing indicate a broad basis upon which opinions may be expressed, and if members will only give their own experiences, some solid good may accrue from the discussion which the author hopes will follow.

Fuel Economy on the North-east Coast: Correction.—In the letter by Mr. Andrew Gemmell on this subject appearing on page 332 of our last week's issue, the word "buy" in the last line but two of the third paragraph should read "bring in."

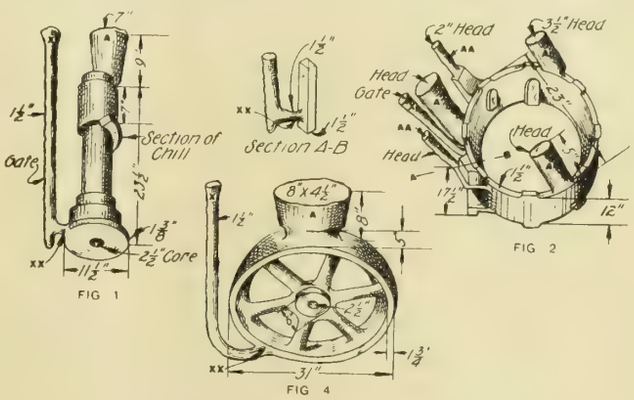
HOW TO GATE AND HEAD STEEL CASTINGS PROPERLY.*

BY RALPH D. WEST.

THE economical and practical production of steel castings depends largely upon the preparation of the mould and the subsequent behaviour of the metal during the pouring and freezing periods. In order that the molten steel may enter the mould, a pouring hole or gate must be provided, so that the mould will receive the metal as rapidly as required, according to the size and section of the piece being made. The gate also should be arranged so as not to interfere in any way with the production of a perfect casting.

The steel foundryman must determine the location of the gate in the mould by his knowledge and practical experience, and must give due consideration to the problem of shrinkage. Molten steel in passing from the liquid to the solid form will shrink from $\frac{3}{16}$ in. to $\frac{1}{4}$ in. per foot of length. Therefore, practically all steel castings must be provided with some form of a reservoir to feed or take up the shrinkage as it develops, so as to form a solid casting. The feeder or reservoir is commonly called a head. Green sand has a natural bond, and presents a greater chilling action to the liquid steel than dry sand, thus requiring in most cases a lesser percentage of metal in the head to feed the casting or to offset the shrinkage. It is understood that a dry-sand mould is simply a green-sand mould with a special facing, placed in an oven and dried or baked so as to eliminate the moisture, thus presenting a better surface to the molten steel for final results. The shrinkage problem varies according to the shape and form of the casting as well as according to its sections.

In a foundry where an ordinary steel moulder is given a pattern with simple instructions to head and gate the casting,



considerable trouble is experienced due to defective work. He may have a gate at hand that will answer, for the main point of importance is where the gate or its extremity, the sprue, attaches to the casting. This point can be properly sized and cut with the moulder's tools, while the upper part must be large enough to admit the steel properly. It is often too large, resulting in considerable loss of metal. The head in many cases is peculiar to the pattern at hand, and to obtain the best results ought to be cut and shaped before handing pattern to the moulder.

In some foundries standard gates are prepared for every job that may come up. The heading, however, is left open to the moulder. This method of procedure is not always practical, but when it can be followed the decrease in the percentage of bad or defective work will soon pay the expense of such a department. It is to the foundry what a tool room or jig department is to the machine shop. There is no question but that an efficient moulder can rapidly improve his knowledge of heading and gating by making it his special work, thus relieving the foreman of this important duty. This gives a tone to the foundry system that goes a long way towards accuracy and the repetition of good results. The problem of gating and heading would be very simple if all castings presented regular standard forms, but, as is well known, the engineer of to-day must build efficient machines, and this involves little consideration for the foundryman. It is his problem alone to produce solid, perfect castings from a net-

* Abstract of paper presented at the Cleveland meeting of the American Foundrymen's Association, September 11th to 15th, 1916.

work of confused shapes and sections run together, light to heavy and curved to straight and at any angle. A number of examples of practical gating methods will now be considered.

The casting shown in Fig. 1 is a cylindrical casting which is to be finished all over. The top under the head forms a cut pinion, the bottom plate of the casting being a friction surface for a brake. The form of the casting is simple, but as a perfect, solid job must be obtained, it is preferable to cast it on end with a large head on top. The gate or sprue must be run to the bottom of the mould so as to give clean steel in the finished job. Two practical points must be observed in forming the mould. First, in cutting the sprue, the area of the cross-section at XX must be made smaller than the cross-section of the casting, otherwise when the gate freezes it will pull a piece

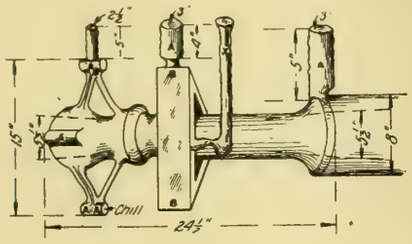
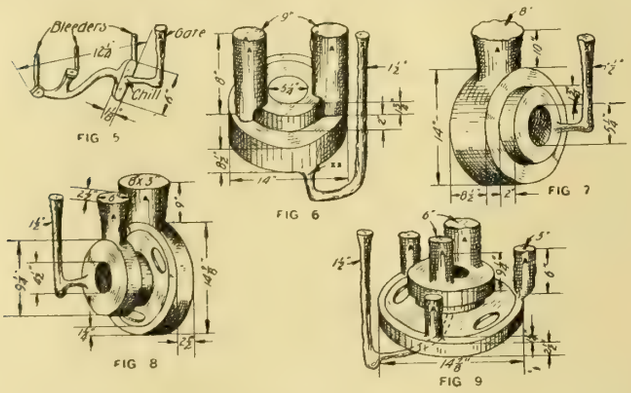


FIG. 3.

out of the casting at the joint. Secondly, the moulder must be careful to remove the sand around the head before the setting sets, so as to avoid a check or crack in the main body. One way to avoid such losses is to place a chill ring around the pattern at the point shown. This method will answer in some cases, but not in all. The casting illustrated being heavy at the bottom will require feeding, therefore placing a chill at the middle would not allow the head to feed the bottom. This would leave shrinkage in the lower end. If the middle section of such a casting is too light to feed the bottom, the foundryman must use his judgment in regard to using two large heads, one on each end. In reply to three letters of enquiry, two foundrymen outlined methods of casting on end, as described, and a third suggested that the pattern be placed in a horizontal position, with a head at either end.

Fig. 2 shows a standard form of circular shell casting, in this case designed for a magnet frame. Experience has taught that it is advisable to cast, as illustrated, with three or four heads on the rim, according to the section of the casting, and to gate between the feet with a bottom gate. The main points to be considered about such castings are, first, to properly feed the heavy sections called pole pieces, and, second, to gate so as to distribute the metal as evenly as possible around the circle. The poles, if concealed below the top section, will have to be



chilled either by nailing or placing iron chills in the rear of the mould, held in place in the sand form.

The gate should be located as near the bottom as possible and so directed as not to cut or wash the inner surface of the core when entering the mould. Also, caution is necessary at the point of connection marked XX, as outlined in the discussion of Fig. 1. Particular attention is necessary in all circular forms to relieve the casting of strains, by digging out the centre core as soon as the metal is set. Some foundrymen pour water into the centre of large cores to soften them at once. This is known as a water gate.

Fig. 3 illustrates a light shell casting having extensions in the form of legs terminating in bosses. They must be fed so as to avoid shrinkage spots. It is possible, when casting such light sections, to omit the necessary heads, providing simply a gate or entrance for steel at one end and an outlet or relief at the other end. The main point in such a casting is to core it so as to give a clean casting and to avoid stresses when the metal shrinks.

Fig. 4 shows a gear blank, a casting common to all foundries. It must be clean and solid with no dirt or shrinkage. At the plant of the West Steel Casting Company a system of casting all gears on end, even as large as 4ft. diam., has been established. The sketch clearly illustrates the method of moulding which gives a clean, solid job. In the heading and gating of such a casting, cast on end, the shrinkage is troublesome and it is necessary to distribute the metal evenly so as to avoid all hot spots, causing checks. In comparison with this method consider a gear cast flat with the four or five heads necessary to feed it. What steel foundry can make a profit out of such waste of metal in heads or risers? Undoubtedly, the heads weigh twice as much as the casting. Communications received from three foundries, however, were two to one in favour of casting flat.

Fig. 5 shows a common form of lever or bracket casting having a curved section with holding lugs. Such castings usually require caution in gating only so as to avoid checking when the metal shrinks. The heavier section or connection must be chilled and the ends relieved with pop heads, or whistles, simply to allow the gases to escape quickly. Figs. 6 and 7 show two methods of casting common bull pinions. The method shown in Fig. 6 is preferable as it gives a clean casting when machined. It is easy to mould with a minimum of labour and weight of metal in the heads necessary to feed the casting solid. The method shown in Fig. 7 not only requires more

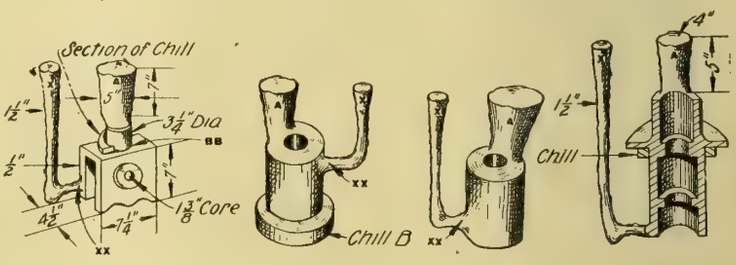


FIG. 10, FIG. 11. FIG. 12. FIG. 13.

labour to form the casting, but requires greater skill to produce a clean casting when finished.

Figs. 8 and 9 show two methods of heading and gating what is known as a double gear. This form of casting is very troublesome, as success in one part is at a sacrifice in the other. Experience has taught that the best results are obtained by the method shown in Fig. 8. This is equivalent to moulding two independent gears, each being provided with feeding and cleaning head. With the method illustrated in Fig. 9 trouble will be experienced on account of shrinkage and dirt in some parts of the cut gears. The smaller amount of metal in the heads is a deciding point to the foundry in favour of the method shown in Fig. 8.

Fig. 10 represents a common form of casting having a bearing section connecting a ribbed or boxed section. It is often difficult to produce a casting which is solid at the base of the shoulder marked BB. If the section of BB is not large enough to feed the lower body, the foundryman must not hesitate to notify the engineer of the necessary stock required to make a solid casting, and to mould accordingly. Some foundrymen place chills around the shoulder BB, but this practice does not allow the heads to feed metal under the chill, and therefore results possibly in a weak finished casting.

Figs. 11 and 12 present two methods of casting heavy bodies in moulds so as to eliminate shrinkage as much as possible. This refers to dry-sand moulds where the castings are finished all over. Fig. 11 shows a casting setting on a chill. It is gated at the top, the metal falling on the chill. This method allows the hot metal to flow directly into the head, requiring only a small amount of steel, possibly 20 per cent., to feed a solid casting. Fig. 12 shows a common method of moulding such a casting, with a bottom gate and a large head on top. Steel foundrymen all know that to get a solid

casting by such plain methods requires at least as much weight in the heads as in castings.

Fig. 13 illustrates a standard collar or sleeve, a troublesome casting, used by many automobile builders. The shoulder marked "chill" has no direct way of feeding the metal above and at each end, being too light in section to feed the inside section. It therefore becomes necessary for the steel foundryman to use his best knowledge, and set all the metal evenly by placing chills at the under section, as shown. Solid, perfect steel castings are often produced by pouring the metal slowly, being sure that enough steel passes through the mould and into the head, the casting setting as the pouring finishes.

A method used in some foundries for moulding and pouring small castings is called multiple or stack moulding. The gate enters the mould on the side, allowing the gases or riser to flow off at the opposite side. This system is troublesome, especially when only one gate is used, as the confined gases will not allow the steel to fill the bottom moulds.

There are many more forms of castings which might be described, but the foregoing will offer sufficient points for consideration. To-day steel foundrymen are more or less ignorant of their associates' practices. The gate must be opened up in order to obtain more knowledge. This knowledge will lead foundrymen on to learn more, and through learning they can obtain some wisdom. Thus a theory in relation to practice will be developed.

APPLIANCES FOR HANDLING MATERIAL AT PORTS.*

BY SIR JOHN PURSER GRIFFITH, M.A.I., M.INST.C.E.

MY colleagues on the Council have done me the signal honour of asking me to deliver the twenty-fourth "James Forrest Lecture," and have selected as the subject "The Development of Appliances for Handling Raw Materials and Merchandise at Ports and other large Centres of Traffic." I have accepted the responsibility as an act of homage and affectionate regard for Mr. James Forrest, whom so many of the old members of the Institution regard with personal friendship, and who has said that "the chief happiness of his life has been to witness the prosperity and usefulness of the Institution."

As my life has been spent in close association with harbour and port engineering, I have been brought face to face with problems closely associated with the import and export trade of our country. If I therefore dwell specially on the handling of materials and merchandise in ports, and appear to overlook many of the similar problems associated with the internal trade and economy of our land, I trust charitable criticism will be extended to me. The subject chosen by the Council is one of great and increasing importance; but it covers a world-wide field. It is obviously impossible to treat it in detail within the limits of a lecture. The numberless appliances and the various conditions to be dealt with would provide materials for many such lectures. I need only mention such books as "The Mechanical Handling and Storing of Material," by Mr. George Frederick Zimmer; "Cranes," by Anton Böttcher, translated by A. Tolhausen; and the classical work of Prof. Adolf Ernst, of Stuttgart, entitled "Die Hebezeuge," to show the extent of the subject, and how much thought has been given, both at home and abroad, to the design and construction of such appliances. All that I can do in the short time at my disposal is to bring under your notice the objects aimed at by the development of such appliances, and what I believe to be the economic advantages gained by their use. I also propose to touch on some striking examples, and finally to submit for your consideration a plea for their extended use on the ground of the benefit they are capable of conferring upon mankind.

The Object of Appliances for Handling Materials.—What, then, do we aim at by the introduction of appliances for handling raw materials and merchandise at our ports? I think it is a fair answer to say that it is to reduce the cost of raw materials and the finished article to the consumer. Reduction in the cost of transport between the source of supply and the manufacturer or consumer is the primary object of such appliances. Quick loading and discharge of vessels is an important factor in freight charges. The ship represents capital invested, and has to earn sufficient in freight to cover interest on capital, sinking fund, or depreciation, working and maintenance expenses, including port charges. For each particular ship this can be represented by a daily charge, and is so represented in chartering a ship by the charge per day for demurrage, to cover delays in port by the merchant or consignee, beyond the period allowed in the charter for the discharge of the vessel. It is obvious that the port which gives vessels the most rapid dispatch will become especially popular with the shipowner, and favourably influence freights to that particular port.

The late Sir William White, at the Engineering Conference in 1907, made the following striking remarks: "As a looker-on it has been obvious to me for many years that greater rapidity in dealing with cargoes must be the essence of success in commercial operations. It was also shown by Dr. Inglis many years ago—on the basis of information supplied by shipowners—that one controlling condition in the profitable running of cargo steamers is the time they remain in port for the purpose of shipping or discharging cargoes, during which time freight earning must be interrupted."

The Influence of Rapid Discharge on Port Charges.—The rapid clearance of ships in our ports is a matter of vital importance from the port point of view. The quay walls of a port are in general the most costly item of port equipment. The earning power of the port may, with advantage, be referred to the income derived per lineal foot of quay, and the cost of the port may be referred to the same unit.

The cost of the port per lineal foot of quay will include the capital expenditure on the quay walls, docks, roads, tramways, sheds, power and lighting appliances, and the outstanding capital cost for the dredging, lighting, and buoying of the harbour. These represent a capital sum on which there is an annual charge for interest and sinking fund. To this must be added the annual expenditure on the maintenance and working expenses of the port, together with establishment charges. If the aggregate sum representing these annual charges be divided by the length in feet of the quay berths, we arrive at the annual expenditure on the port per lineal foot of berthage. In a similar way, if we find out what the annual income of the port amounts to from dues on shipping and goods, rents and other charges, and divide the sum total by the length of quay berthed in feet, we arrive at the earning power of the port per lineal foot of berthage. We are now in a position to say whether the port as a whole is solvent, or whether the port charges are sufficient or excessive. We arrive, in fact, at what the average earning power of each foot of quay should be.

In a detailed examination of different portions of the berthage on these lines it will be found that some quays pay much better than others; that, in fact, some quays are much more efficiently worked than other portions. It will generally be found that berths appropriated to fixed and regular trades yield a higher return than the open berths devoted to the general trade of the port. This naturally follows, because berthage is not appropriated to a particular trade unless that trade is regular and of sufficient volume to warrant an appropriation. This all points to the necessity of insisting on rapid discharge and clearance of ships at these open quays. From the annual expenditure per lineal foot and the income per lineal foot of quay, we can at once put our finger on the weak spot and say that such and such a quay must be worked at greater pressure. The importance of appliances for handling raw materials and merchandise immediately becomes evident. It is only by such appliances that you can ensure the rapid discharge of the ship, make your port financially sound, keep down port charges, and thus make your port attractive to both shipowners and traders.

Ship's Own Appliances for Handling Cargoes.—It is impossible when dealing with the subject of this lecture to omit all reference to such appliances as are fitted on vessels in certain trades for handling cargoes both for loading and discharging with the ship's own gear. From very early days the winch worked by hand was in use on sailing vessels for raising cargoes from the holds. With the advent of steamers, the hand winch was replaced by the steam winch, worked from the ship's main boilers, or from an auxiliary boiler. This arrangement is still in general use. Steamers in the oversea trade frequently call at ports where there are no shipping quays, and the cargoes are loaded from or discharged into lighters or other vessels over the side. To meet this, and also to accelerate the speed of loading or discharge, derricks have been attached to the ship's masts, and even special derrick posts have been fitted. By this means derricks worked by steam winches command the vessel's hatchways, and also lighters or vessels along-

* The "James Forrest" Lecture, 1916, delivered before the Institution of Civil Engineers.

side. Cases exist of vessels in which the ordinary masts have been dispensed with, and only derrick posts fitted; and instances have been quoted in which a vessel so fitted, carrying over 10,000 tons of ore, has been discharged at the rate of 300 tons per hour. Where a vessel is engaged in a regular trade between fixed ports to which regular berthage is appropriated elaborate appliances on the ship for discharging and handling cargo are necessary. It is more economical in such cases to have the appliances ashore, where they can be kept constantly at work. Cargo-handling plant on the ship is, of course, only used when the vessel is in port, and lies idle during the voyage, and for this reason is not as economical as shore plant.

There are, however, some large ports, such as Hamburg and Rotterdam, on great inland waterways, serving an immense hinterland, where ships discharge portions of their cargoes on to the quays, and portions into the huge river barges found on the rivers Elbe and Rhine. Steamers trading to these ports are, therefore, equipped with their own cargo-handling plant. It would appear that this ship equipment has had a deterrent effect on the proper equipment of ports. Shipowners having their own appliances have declined to make concessions in freight to ports which possess their own equipment. Merchants have declined to pay for harbour equipment when the shipowner's contract covers hoisting the cargo out of the hold and placing it on the ship's rail. So well equipped were the steamers of the Hamburg-American line, trading between Hamburg and Boston, that the steamship company advised the Boston port authorities that it did not desire a permanent handling equipment established in the port. It would appear that the German Company, with its up-to-date ship equipment, hoped to be able to capture the trade of Boston by embarrassing its competitors, who might depend more upon port equipment supplied by the local authorities.

Our portal authorities have been slow in realising the importance of rapid dispatch in loading and clearing ships frequenting their ports. They have frequently checked the extension of port equipment by excessive charges, forgetting that it is not so much making a profit out of such appliances which should be sought as making the port as a whole more efficient and economical. Shore equipment is essential for the handling of materials on shore, and for hastening the clearing of wharves and sheds. This is as essential as the discharging of the vessel, for if the landed cargoes are not removed rapidly the discharge of vessels is delayed for want of quay space upon which to land the cargoes. The congestion of our ports from which the nation has suffered during the present war has been largely due to imperfect facilities for handling the goods when landed.

My attention was drawn to the importance of port equipment for handling cargoes more than 40 years ago in a curious way. The late Herr Dalmann, the chief engineer of the port of Hamburg, visited Dublin in the early seventies to see the operations of building, lifting, and laying the great masonry blocks of 360 tons which the late Dr. Bindon Blood Stoney used in the extension of the quays of Dublin harbour. Herr Dalmann at the close of his visit invited me to Hamburg, and amongst other attractions mentioned that a greater tonnage of shipping was accommodated in Hamburg per lineal foot of quay than in any English port. My curiosity was excited, and I determined to see how this was accomplished. Its importance was brought home to me, as I knew that at the time the costly deep-water berths in Dublin were the least remunerative quays in the port. The result of my visit was to show me that the equipment of the Hamburg quays with cranes had been carried out to an extent quite unknown in England and our British ports, and arrangements as regards charges for their use were adopted which made it advantageous for the trader to use them. The result was that vessels were discharged and loaded rapidly, and the costly quays worked efficiently. As regards the development in the handling of raw materials and merchandise, my experience in the port of Dublin, extending over a period of nearly 50 years, covers the period of change from purely manual labour in the discharge and loading of vessels, to the use of machinery and mechanical appliances on a very considerable scale.

I now propose to give some instances of appliances for handling coal, ore, grain, oil, timber, heavy machinery such as engines and boilers, general merchandise, and packed goods. These have been selected, not with the intention of suggesting that they are suitable for general application, but as striking examples of special appliances for particular purposes, which may prove an incentive to the extension of mechanical appliances for handling raw materials and merchandise in our ports and centres of traffic.

Coal Handling.—In the year 1869, when I first became connected with the Engineering Department of the Port of Dublin, all coal entering the port was carried in sailing vessels, of which the Whitehaven brig was the typical example. With a favourable wind these vessels entered and left the port in fleets, with the result that the coal supply of the city fluctuated within wide limits, and prices varied accordingly. These vessels were practically the coal stores of the city, lying in the port for weeks. The coal was raised from the ship's hold in wooden tubs by a hand winch worked by a couple of the crew. The coal was filled into sacks, weighed on a scale fixed on the ship's deck. It was then carried ashore on men's backs to carts for distribution to the customers. The price of coal was exhibited on a board at the ship's gangway. Even for the gas supply of the city coal was handled in the same way, and large storage had to be provided at the gasworks to meet the uncertain supply due to weather conditions. Many serious fires occurred in these large coal stores due to heating of the coal.

What a change has come over the scene! The sailing collier has disappeared and been replaced by steam colliers, which arrive in port in the morning and leave the next evening. These vessels sail with clock-like regularity, and are designed to carry the maximum of coal in vessels of suitable size and draught for the particular coal port with which they trade, and they are engined for speeds necessary to meet the tidal conditions of these ports. The modern collier is designed with large hatchways to facilitate the loading and discharging of coal and to reduce trimming.

Coal-loading Appliances.—In the matter of loading coal into ships at the coal ports, there has perhaps been less change in principle than in the discharge of cargoes. We find the coal staith in use in the river Tyne at a very early date. The object was to bring the loaded colliery wagons into such a position that the coal could be discharged by gravity and carried direct into the holds of vessels. The modern staith is merely a development of this idea, and is so designed as to allow trains of coal wagons to discharge in quick succession. In some cases the wagons are run up on high staging commanding the coal shoots; in other cases the wagons loaded with coal are raised vertically to the necessary height for tipping, while in some recent instances the coal wagons discharge into a coal hopper below the ground level from whence the coal is delivered by elevators into the ship's hatches.

The only examples of American coal-loading appliances which I propose referring to are the coal hoists at Toledo, Ohio, constructed by the Brown Hoisting Machinery Company, of Cleveland, Ohio. These hoists are designed to raise and dump cars containing 100 tons of coal, and records show that each machine will handle from 40 to 50 cars per hour. The car is pushed into the cradle by the "Ground Hog." It is clamped on the cradle, and as the cradle is hoisted the wagon is turned over through an angle of 160° and emptied. Trimming of coal in the holds of the primitive colliers was a costly operation; but this has been reduced to a minimum in the modern steam collier, with its large hatchways and capacious and unobstructed holds. This not only facilitates loading, but also discharge, permitting of the discharge by mechanical means.

Coal-discharging Appliances.—The discharging of coal from the ship is still, it may be said, in a transition state. Although the methods described of discharging the old-sailing collier in Dublin are out of date, yet a considerable quantity of coal is excavated in the holds by manual labour, and the buckets or skips are filled by the same men. The bucket carrying from 29 cwt. to 30 cwt. of coal is then hoisted either by the ship's own tackle or by cranes on the quays. Considerable advances have been made in the use of grabs or excavators to dig the coal out of the ship's holds, and reduce manual labour to a minimum.

Coal Handling and Water Carriage of Coal on the Aire and Calder Navigation.—One of the most striking systems of the handling of coal from the colliery to the coast for shipment is that devised and carried out by Mr. William Hamond Bartholomew, M.Inst.C.E., on the Aire and Calder Navigation. It is probably the most successful case of inland navigation in England at the present time. This navigation forms an important section of the waterways connecting the ports on the Mersey with those on the Ouse and Humber on the east coast, and passes the coalfields of

West Yorkshire, and is connected by water with the coalfield of South Yorkshire. The port of Goole on the river Ouse is the eastern terminus of this navigation, the waterway of which has been greatly improved and adapted to mechanical haulage. The principal locks have been enlarged to 460ft. in length, 22ft. in width, and with 9ft. of water over the gate sills, while the waterway has a minimum sectional area of 457 square feet.

The improvement of the waterway has allowed of the compartment boat system, which has been designed by Mr. Bartholomew especially for the carriage and shipment of coal and other minerals. Each compartment forms a rectangular boat, and carries 40 tons of coal. The compartments are coupled together and formed into a train consisting of a tug and 20 or 30 compartments and carrying from 800 tons to 1,200 tons of coal. Each train is worked by four men. The several compartments are loaded at the colliery staiths, and on arrival at Goole are floated into the cradles of powerful hydraulic hoists, in which they are secured, raised to the required height, and tipped over, discharging their contents into shoots and thence into the ship at the rate of from 200 tons to 300 tons per hour, according to the suitability of the ship to receive such cargo. The system has the further advantage of enabling the compartments to be taken out of the water on railway trucks specially designed for the purpose, and transported upon them over the colliery railways to be loaded at the pit head, and returned loaded by the same means to the waterway. In the case of one colliery about 1½ miles from the waterway, compartments are transported over gradients of 1 in 27.

Comparing the compartment system of conveyance with that of ordinary barges, it would need eight or 12 of the latter of 100 tons each to convey the equivalent of the compartment trains under consideration, and would require 16 or 24 men to work the barges, and eight to 12 horses to haul them, whilst the time required for transhipment from ordinary barges and the cost involved make such an operation practically prohibitive. It is worthy of note that this navigation is in close touch and competition with the North-eastern Railway, the Lancashire and Yorkshire Railway, the Hull and Barnsley Railway, the Great Central Railway, and the Great Northern Railway.

(*To be continued.*)

HEAVY-OIL ENGINES.*

BY S. B. DAUGHERTY.

IN a consideration of the oil engine, the questions at once arise: What kind of oil is suitable? Are supplies of fuel available in sufficient quantities in various parts of the country? Will the probable production of oil in years to come be equal to the demand? To answer the first question requires a word of explanation as to the types of oil engines. Broadly, there are two—the low-compression engine, wherein ignition is effected by the injection of the oil spray against a heated surface, or even by an electric igniter, as in gas engines; and the high-compression or Diesel type, with ignition from the heat of compression of the air charge. The low-compression engines are the simpler and cheaper, but, on the other hand, suitable fuels for use in them are fewer and higher-priced, and the thermal efficiency is less. These limitations tend to restrict the use of low-compression engines to smaller installations. Suitable oils are kerosene, the lighter distillates, and light crude oils.

The high-compression or Diesel-type engines can in general utilise any liquid fuel. It is to be remembered that there is no strict line of demarcation between the types, but that they tend to merge one into the other. The grades of suitable oils vary inversely as the grade of the engine—the cheaper and simpler the engine, the higher the grade of oil required; the more elaborate and specialised the engine, the lower the grade of oil which may be successfully used.

The date of the beginning of the production of petroleum or mineral oil in the United States is recorded in Government publications as 1859, the production of that year being 2,000 bbl. of 42 gals. each. The United States production marketed in 1914, the last year for which statistics are available, was 265,762,535 barrels.

There are six major oil fields of the United States: The Appalachian, the Lima Indiana, the Mid-Continent, the Illinois, the Gulf, and the California. The quality of the oil produced in the Appalachian field is the best. It is light, yielding a large percentage of gasoline and kerosene, and paraffin is obtained from the residuum; the Lima Indiana oil is also light, but contains sulphur; the Illinois oil contains less sulphur than Lima Indiana oil, but contains some asphalte as well as paraffin; oils of the Mid-Continent field contain paraffin and asphalte, and show considerable variation; those from the Gulf field contain considerable sulphur, while the California oils in general contain much asphalte and considerable sulphur. Some of the California oils are valueless to the refiner, and find their market as fuel oil or as road oil.

In addition to the oil produced in the United States, there is an enormous potential production in Mexico. This oil is

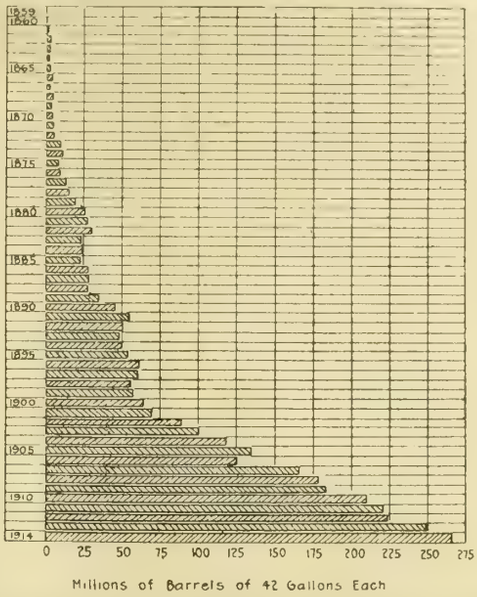


FIG. 1.—ANNUAL OUTPUT OF PETROLEUM IN THE UNITED STATES.

asphaltic, and contains often as much as 3½ per cent. sulphur. It finds a ready market as fuel oil, and can be sold in the ports of New England at a price that allows of its being used as fuel under boilers in competition with coal. In Florida, Mexican crude is used extensively. A general survey of the statistics shows that the total production of oil in the United States is increasing. This increase is in the lower-grade oils, as the production of the Appalachian field is decreasing, even though the price has recently been maintained at a fairly high level.

New fields are being discovered, and the limits of old fields are being extended. It is probable that for many years the total production will increase. In fact, it is the opinion of

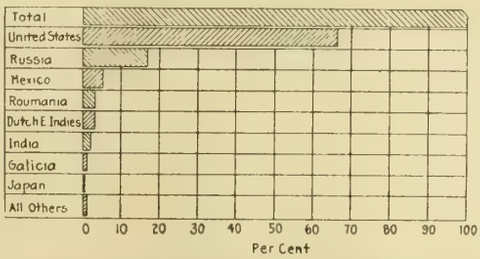


FIG. 2. WORLD'S PRODUCTION OF PETROLEUM IN 1911.

experts that the petroleum resources of the world are relatively undeveloped. Some fields are enormously productive, as, for instance, the Cushing pool, which a year ago was producing at the rate of about 30,000 bbl. per day; the production of this field has decreased so that now it is about 12,000 bbl. daily.

Consumption of petroleum products is constantly on the increase. This applies particularly to gasoline. It is estimated that the automobiles of this country are consuming over 1,000,000,000 gals. annually. In addition to this amount, the yearly consumption of gasoline for other purposes is about 500,000,000 gals. It is in this enormous demand for gasoline that there is an assurance of a reasonable supply of oil suitable for use in engines. Part of this supply is the residue from refining operations, and a great portion is in the lower grades of crude oil discovered in the search for new supplies. Fig. 1

* Paper presented at a meeting of the Chicago section of the American Society of Mechanical Engineers, March 17th, 1916.

shows the annual production of petroleum in the United States from 1859 to 1914. Fig. 2 shows the total production of the world for 1914, and the percentages produced in the different countries.

A first impression would be that any decided increase in the number of oil engines in use would create such a demand for fuel oil that prices would advance to a figure which would make the oil engine unprofitable. But this does not take into consideration the fact that in many cases the oil engine supplants an oil-fired boiler, and that but one-fifth to one-tenth of the oil burned under the boiler is required for the oil engine, the remainder being available for other purposes. It must also be remembered that the price of fuel oils is largely determined by the price of other fuels. Heat units in oil must not be much higher priced than heat units in other fuels, or there is no market for the oil. For many years the price of low-grade oils will be determined by the demand for other purposes than use in oil engines.

Oil Engines, Diesel and Semi-Diesel.—This paper will consider Diesel-type engines particularly. The Diesel engine is the most economical prime mover yet designed. It is now 22 years since the engine was patented in Germany. The engine was developed by the Augsburg-Nürnberg Company. The first commercial engine was put in service in 1897, and, according to the Augsburg-Nürnberg Company, was still in service and running satisfactorily in 1911.

The Diesel engine is unique, in that it was designed to fit a theory. Some of the paragraphs in Diesel's patent show clearly that his calculations were not entirely correct; for instance,

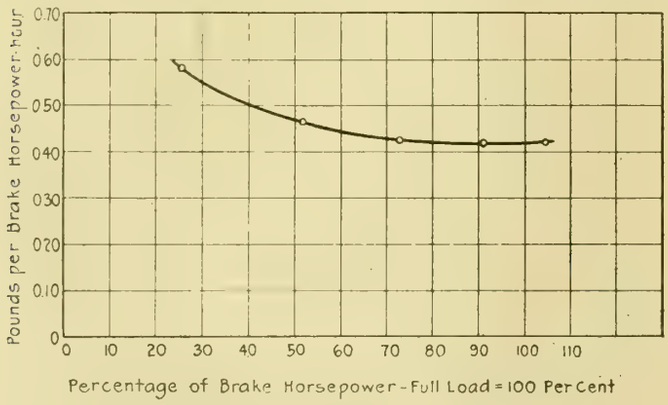


FIG. 3.—FUEL CONSUMPTION, 4-CYCLE "SNOW" OIL ENGINE, FROM ACTUAL BRAKE TESTS.

his statement that there is "no increase in the temperature produced on the introduction of the fuel, or at most only a very slight one, and the highest or extreme temperature is produced by the compression of the air. It is, therefore, under control and will be kept within moderate limits, and, moreover, in view of the cooling of the products of combustion by the subsequent expansion, no artificial cooling is required for the cylinder, the mean temperature of the gases being such that the parts of the engine can be kept tight and lubricated"; also that "the exhaust may be cooled by expansion below the temperature of the atmosphere and utilised for refrigerating purposes." Experiment has proven these statements incorrect, but in its essential features his theory was sound. The first claim in his patent covers the engine so completely that, so far as I am aware, no infringement was ever attempted. This is the claim: "The herein-described process of converting the heat energy of fuel into work, consisting of first compressing air, or a mixture of air and neutral gas or vapour, to a degree producing a temperature above the igniting point of the fuel to be consumed, then gradually introducing the fuel for combustion into the compressed air, expanding against a resistance sufficiently to prevent an essential increase of temperature and pressure, then discontinuing the supply of fuel and further expanding without transfer of heat."

The first Diesel engine was a vertical machine, and this design was followed in subsequent engines until it became so standardised in Europe that the opinion prevails to a great extent that there must be some vital reason for the adoption of the vertical type. The first commercial engine was a twin-cylinder vertical engine of 60 b.h.p. Both horizontal and vertical Diesel engines are now being built in the United States, and the expiration of Diesel's patent in July, 1912, was the occasion of many builders entering the field.

In addition to Diesel engines, the De La Vergne type FH engine should be mentioned. It is classed as semi-Diesel, but its equipment includes all of the essentials of a Diesel engine, and the compression needs only to be raised from about 350lbs. to 500lbs. in order to bring it into the Diesel class. The economy of this engine is practically the same as that of the true Diesel type.

Economy of the Diesel Engine.—As stated, the main feature of the Diesel engine is its economy. The measure of efficiency of a prime mover is the percentage of potential power actually obtained for useful work. In the transformation of heat energy into useful power various losses occur. If steam be the medium, there will be a loss of heat in the boiler, due to radiation, to the escape of heat into the stack with the gases formed by combustion of the fuel, and to imperfect combustion of the fuel. Heat in the steam is lost by radiation, and a very considerable amount is rejected in the exhaust. Friction accounts for a further loss, and so, with steam as a prime mover, the percentage of actual heat in the fuel that is transformed into work ranges from 6 to 16 per cent. For intermittent operation, where a considerable portion of the fuel burned is for stand-by service, the percentage may be even lower. In the internal-combustion engine the heat losses are due to radiation, to heat carried off in the jacket water and in the exhaust, and to friction. The principal saving is in the reduction of the amount of heat lost in the exhaust.

The effective thermal efficiencies of various prime movers are about as follows:—

	Per cent.
Non-condensing steam engine	8·4 to 6·6
Condensing steam engine and turbine using superheated steam	15 „ 10
Suction gas engine	23 „ 18
Four-cycle Diesel engine	34 „ 32

The significance of this Diesel-engine economy can best be appreciated by a familiar comparison: Assume that a touring car can be run 12 miles on a gallon of gasoline, which costs 23 cents per gallon and weighs about 6lbs. Assume that the engine has a thermal efficiency of 18 per cent., and that the effective heating value of the gasoline is 114,000 B.T.U. per gallon.

Fuel oil weighing about 7·5lbs. per gallon would have an effective heating value of about 135,000 B.T.U. per gallon. On this basis of relative heat values and efficiencies a Diesel-type engine would drive a car 26 miles on a gallon of oil, as compared with 12 miles with gasoline. But 7·66 gallons of oil can be purchased for the price of one gallon of gasoline, so that the distance covered for 23 cents worth of fuel would be 200 miles with oil and 12 miles with gasoline, or 16·6 times.

Fig. 3 shows the fuel-consumption curve of a single-cylinder four-cycle engine. At loads from 80 per cent. to full load the consumption is practically constant, and at the rate of 0·42lb. per brake horse-power hour. At this rate one gallon of oil will furnish about 18 brake horse-power hour, and the cost for fuel per brake horse-power hour with oil at 3 cents per gallon is $1\frac{2}{3}$ miles. To supply 100 h.p. for 10 hours would require $55\frac{1}{2}$ gals. of oil, costing $1·67.

The opponents of internal-combustion engines, both gas and oil, always state that these engines are economical only when operating near maximum load, and that the economy falls off rapidly as the loads decrease. Observe on this curve that the load is approximately 42 per cent. where the consumption curve crosses the 0·5lb. line, and that the consumption at half load is 0·47lb. The fuel consumption for a 10-hour day, running a 100 h.p. engine at half load, would be about $31\frac{1}{2}$ gals., costing, at 3 cents per gallon, 95 cents. It is evident that the fuel expense for keeping an engine running on friction load is very slight. By actual test on a 65 h.p. engine, full speed with load was maintained on 1·1 gals. per hour.

Vertical v. Horizontal Diesel Engines.—One of the outstanding features of Diesel-engine manufacture in the United States is that, in general, those manufacturers who have done their own designing have brought out horizontal engines, while those who are building vertical engines have purchased the designs abroad.

The advantages of the horizontal engine, as enumerated by a concern with an established reputation as builders of vertical engines, are: Lower price; easy survey and convenient atten-

dance; better distribution of stresses on the crankshaft and main bearings; better lubrication of bearings; better lubrication of piston; easier cleaning and repair work, especially to pistons, which can be taken out without removing the cylinder head and the valve gear; reduced height of engine room, as all pipes are laid in trenches under the floor and do not obstruct the room.

In a comparison of vertical and horizontal Diesel engines the detail most discussed is the piston. Vertical builders call attention to the weight of the piston, and the side pressure thereby produced on the cylinder bore, in the case of the horizontal engine. The fact that the first Diesel engines were built vertical, and that excessive height was undesirable, probably led to the use of trunk pistons. For the same reason a connecting rod of a length but slightly more than five cranks has been used in vertical engines. An analysis of the forces prevailing throughout the cycle of operations shows that the side pressure on the cylinder walls, due to the angularity of the connecting rod, is far greater than the pressure due to the weight of a piston, even though the piston lies horizontally. Any increase in connecting-rod length means a proportional decrease in the side thrust. Ordinarily an increase in the length of the connecting rod of one crank length decreases the side thrust an amount equal to the weight of a piston and wrist pin, or, in other words, a vertical trunk-piston engine with a connecting rod five cranks long is subjected to about the same side pressure on the cylinder wall as a horizontal trunk-piston engine with a connecting rod six cranks long.

The magnitude of the forces involved in the engine is not generally realised. Weight is obvious, but loads due to fluid pressure inside of cylinders and the reactions resulting therefrom are not so readily appreciated. For example, with a connecting rod five cranks long, and the engine crank 45° from dead centre on the working stroke, the side thrust on the piston, not considering the modifying effect of inertia of the reciprocating parts, is about 41lbs. per square inch of piston area. For a 19in. diameter piston, this is $284 \times 41 =$ 11,640lbs. The weight of a 19in. piston with wrist pin and one-half of the connecting rod is approximately 1,600lbs. The side thrust due to angularity of the connecting rod for this condition is about 7·3 times the weight of piston. In actual running, the force transmitted to the crank pin through the connecting rod is reduced by inertia effects, so that the side thrust due to angularity is from five to six times the piston weight instead of 7·3 times.

In order to present this feature more clearly diagrams are given showing the pressures acting on the piston during the compression and working strokes; the inertia; the combined inertia and pressures, which is the measure of the effort transmitted to the crank pin; the turning effort on the crank pin, and the resulting thrusts due to the angularity of the connecting rod. The figures on the diagrams are in pounds per square inch of piston area. In these piston effort diagrams, the forces which tend to drive the crank in clockwise direction are shown above the horizontal base line, and those forces that would tend to drive the crank in the reverse direction are shown below the base line.

Beginning with the compression stroke, Fig. 4*a*, note that the crank is driving the piston against a constantly increasing pressure, which reaches 500lbs. per square inch at the end of the compression stroke, Fig. 4*b*. At the beginning of the compression stroke, when the inertia of the reciprocating weights must be overcome, the pressure in the cylinder is low. At the end of the compression stroke the inertia effect is tending to revolve the crank in clockwise direction, as shown in Fig. 4*c*. Note, in Fig. 4*d*, how closely the line approaches the base. An increase in the weight of the reciprocating parts or an increase in the rotative speed of the engine would cause the line to cross the base line, or, in other words, would result in the piston actually pulling the crank during a short portion of the compression stroke; such a condition tends to cause a knock. From this piston-effort curve the negative turning effort on the crank is obtained, Fig. 4*e*, and the reaction on the crosshead due to the angularity of the connecting rod, Fig. 4*f*. On the compression stroke, the tendency is to lift the crosshead throughout the stroke. The upward thrust is maximum near the end of the compression stroke, and equals 14·5lbs. per square inch of piston area. The weight is about 5·2lbs. per square inch, so that the net upward thrust is 9·3lbs. per square inch of piston area, or 10,700lbs. For a 19in. diam. piston, upward thrust is resisted by adjustable gibs bearing on the sides of the crosshead shoe, and no trouble is experienced in making these adjustments so that the engine runs quietly.

At the end of the compression stroke, fuel is injected and the working stroke follows, Fig. 5*a*. The pressures in the cylinder throughout the stroke are indicated in Fig. 5*b*. The inertia diagram for this stroke is shown in Fig. 5*c*. Note particularly, in Figs. 4*d* and 5*d*, the beneficial effect of inertia in reducing the high pressures at the end of the compression stroke and the beginning of the working stroke, and in supplementing the low pressures in the cylinder at the end of the working stroke so that the effort is more evenly distributed.

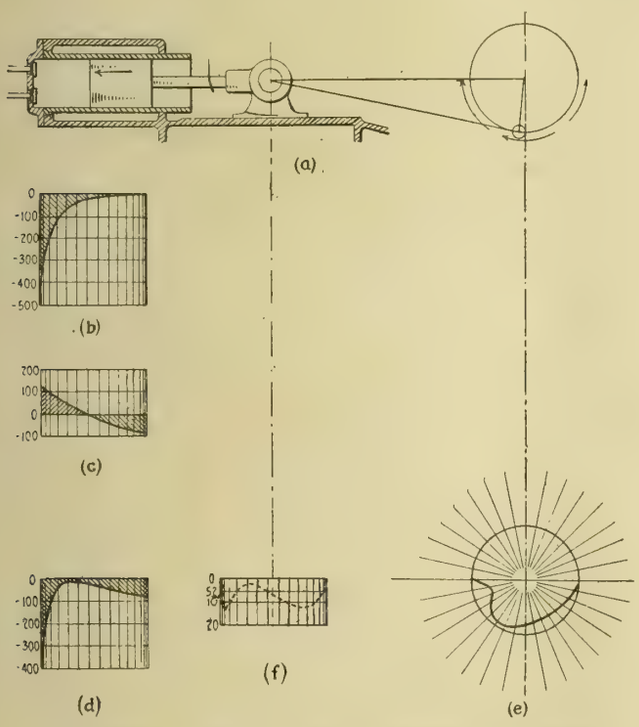


FIG. 4.—PISTON EFFORT DIAGRAMS FOR HORIZONTAL OIL ENGINE. COMPRESSION STROKE.

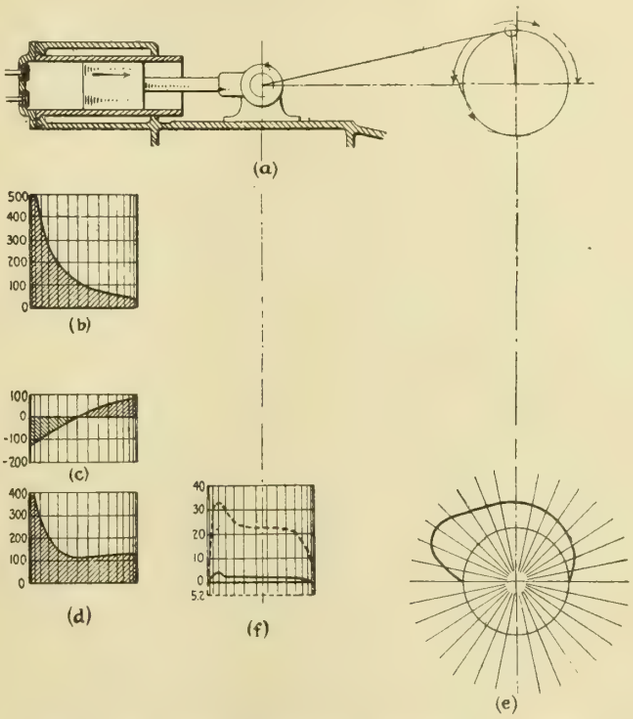


FIG. 5.—PISTON EFFORT DIAGRAMS FOR HORIZONTAL OIL ENGINE. WORKING STROKE.

(a) Frame diagram; (b) compression diagram; (c) inertia diagram; (d) combined compression and inertia; (e) crank effort; (f) reaction on crosshead guide.

During this stroke the thrust due to the angularity of the connecting rod is all downward, Fig. 5*f*, and reaches a maximum of 32·6lbs. per square inch of piston area. Adding the weight to this, the maximum downward pressure is 37·8lbs. per square inch of piston area, or 10,700lbs. For a 19in. diam. piston, note particularly that if the cylinder were vertical there would still be a maximum side thrust of 9,250lbs.

From the foregoing it will be very apparent that it makes but little difference whether an engine is built vertical or horizontal in so far as side pressures are concerned. In the case above analysed, weight adds but 16 per cent. if the maximum pressure is considered. The advantage of the horizontal engine in general, and the crosshead type in particular, is in its superior accessibility. In the case of a vertical trunk-piston engine it is necessary to practically dismantle the engine in order to get at the piston, piston rings, or wrist-pin bearings. In most cases the valve gear and the cylinder heads must be removed, the connecting rod must be disconnected at the crank pin, and the piston and piston rod then lifted out through the cylinder.

Compare this procedure with that necessary in the horizontal engine: The sheet-steel crank splasher is removed; then the connecting rod is disconnected, at the crank pin in the case of a trunk-piston type, or more simply at the wrist pin if the engine has a crosshead, and the piston is then removed from the open end of the cylinder. The actual time required to remove a piston and crosshead of a 19in. by 33in. engine was 20 minutes. The piston was wiped clean and replaced in 30 minutes, making the total shut-down 50 minutes, as compared with about one day of 10 hours to accomplish the same thing in the case of a vertical engine.

Type of Diesel Engine and Lubrication.—The matter of cylinder lubrication is another feature of superiority in horizontal engines. In the vertical type it is absolutely essential, in order to secure a distribution of the lubricant around the cylinder bore, to supply the oil through a number of feeds, as many as four per cylinder on the smallest sizes and more on larger diameters. A horizontal cylinder, on the other hand, even of the largest size that is practicable to build, can be effectively lubricated over its whole surface from a single feed on the upper side. Gravity helps to distribute the oil.

In any internal-combustion engine some of the lubricating oil is carbonised. In a vertical engine this carbon tends to work down past the piston, fouling the rings and dropping into the crank pit, where it becomes mixed with the bearing oil. In the horizontal type, much of this carbon is pushed into the counterbore, whence it can be removed through a blow-off valve in the bottom of the cylinder. Such portion as works by the piston can be caught in the frame and prevented from mixing with the bearing lubricating oil. Even the main bearings in a horizontal engine are more effectually lubricated. During the working stroke, when the pressures are highest, the main shaft is partly lifted from the bottom shell, allowing the lubricant to fill the space. Then on the two idle strokes, the exhaust and inlet, inertia effects tend to bring the shaft first against one side of the bearing, then against the other, thus effecting a very thorough distribution of the oil.

(*To be continued.*)

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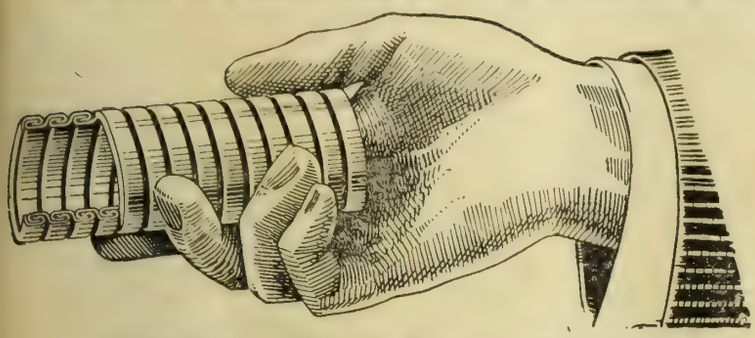

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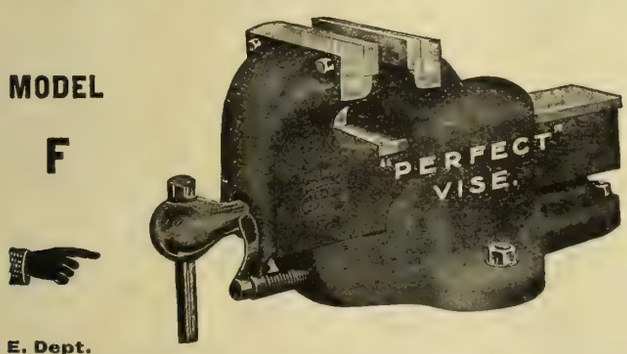

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Coal Production and Economy.

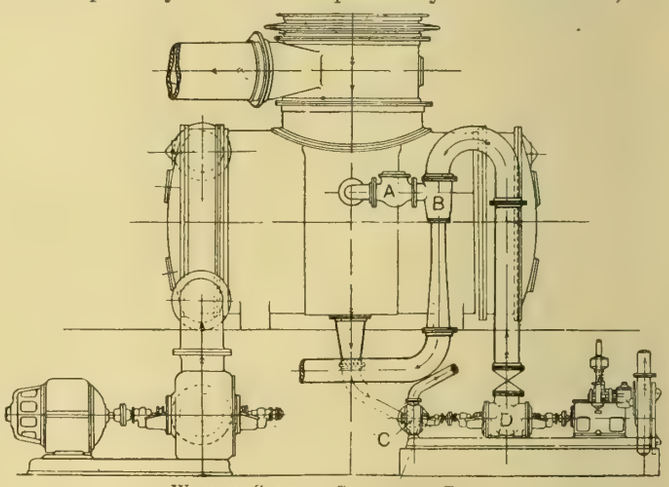
As the war progresses, the demand for fuel grows, and at the same time the husbanding of supplies and the practice of economy becomes more and more pressing. This is not surprising to those who view the carrying on of the war in its widest aspects, as its executive problems are mainly engineering ones, and consist in the furnishing and accelerating quantities of munitions and machinery, whose manufacture depends on coal as the primary source of energy. The serious results which may follow from contraction of output was clearly stated by the Prime Minister some days ago in his remarks to the representatives of men engaged in coal mines, on the subject of absenteeism. We do not propose to dwell on this, though it must have been a painful shock to many to learn that in this time of national stress there are sections of men in the pits who place comfort and indolence before patriotism, and that while the great majority of their countrymen are straining every nerve to meet the common task, they indulge in indolence to an extent which even their official representatives condemn, and which it is admitted could, without excessive effort, be reduced by one-half. Apart, however, from this question of output of fuel, its economical use is also of importance, and in this connection the report issued by the British Association Committee deserves attention. It is universally admitted that our methods both of getting and utilising coal have been improvident, and, notwithstanding our enormous stores and improvements in working, the average price of the raw material has for many years been on the up-grade, as a consequence mainly of higher wages and the adoption of greater precautions to ensure safety, coupled with the fact that the demand is an ever-increasing one. How great the world's requirements are is shown by the fact that

the approximate total of 800 million tons in 1903 rose to 1,250 millions in 1913, a growth practically equivalent to a compound interest rate of 5 per cent. per annum. Whether this rate of growth will continue in the future or what it would amount to in the course of 100 years it would be idle to dwell upon. It is sufficient to consider immediate requirements, and the means by which these may be the better fulfilled. Coal is not only of prime importance as a fuel, but in the hands of the chemist its by-products become the raw materials of numerous other industries. By synthetic processes other products such as petrol, dyes, drugs, fertilisers, and certain explosives are evolved, and economy in the manufacture and use of each of these is of national advantage. Economy of fuel, it will be evident, covers a wide field, and in order to study the various aspects of the question the British Association have appointed a series of sub-committees to deal with them from the standpoints of chemistry, carbonisation, metallurgy, power, and domestic heating. Mechanical engineers have made much progress during recent years, not only in raising the economic efficiency of prime movers, but in the concentration of prime movers in central stations, but much remains to be done before it can be claimed that our national store of energy of coal is being wisely and efficiently expended. The theoretical problem of converting the heat of coal into mechanical work has been largely solved, though it is recognised much saving is still possible by greater co-operation amongst central power stations by the co-ordination of electrical distribution so as to secure uniform output. Amongst small steam power units fuel expenditure is still most extravagant. In individual units it may not seem great, but its seriousness in the aggregate is indicated by some figures given in the report of the Royal Commission on Coal Supplies in 1905. It was there stated that the average consumption of coal per horse-power hour, deduced from a number of typical industrial concerns where information could be obtained, was not less than 5lbs. When it is borne in mind that this would include many economical units, and that in large central power stations the expenditure per indicated horse-power hour is less than 2lbs., it will be obvious that in a great many instances it is three to four times what it ought to be. Much improvement could undoubtedly be effected in many small power installations by the substitution of gas or oil engines for steam engines, or where circumstances permit, by electricity from a central station. In large ones self-interest has led in many instances to the adoption of better appliances in the shape of mechanical stokers, &c., weighing apparatus, CO_2 recorders, calorimeters, and water-measuring devices, but there are still many firms where improvements of this kind could be adopted, and where expenditure would be amply rewarded by the coal saved. In domestic heating there is quite as much scope for economy as in industry, but the question concerns a vastly greater portion of the population, and is infinitely more complex, but the fact that the Royal Commission in 1905 estimated that one-half the coal consumed for domestic purposes might be saved by the installation of better appliances, shows it is deserving of serious study. Domestic heating is closely linked with ventilation and health, not to mention the prejudices of individuals in favour of the open fire, and we are not surprised that the British Association Committee have no cut-and-dried remedy to propose. This, however, only proves the need for full investigation. The more the subject is ventilated the more public opinion will be educated and led eventually to adopt solutions conducive to the end in view.

TESTS OF A WILLANS SURFACE CONDENSER.

THE results of some tests obtained on one of five surface-condensing plants, embodying the Willans & Robinson rotary air-pump system, and installed at the London & South-western Railway Company's Durnsford Road power station, have recently been made public. The station contains five identical plants, each of the same capacity, in addition to two similar plants of smaller size. The main feature of this system is that the circulating water is passed through an ejector, which is shown on the accompanying drawing at B, and takes the place of the ordinary air pump. A separate pump C is provided to withdraw the condensed steam from the surface-condenser, and to return this to the hot well. An automatic non-return valve A is placed between the air ejector and the main condenser body, so as to prevent water being drawn into the condenser in case of failure of the ejector.

There are three common forms of application of the system known as the "series," the "shunt," and the "separate pump" types respectively. In the case of the "series" type of plant, the whole body of the circulating water is passed through the air ejector before entering the condenser; that is to say, the circulating pump is designed for the normal quantity of water required by the condenser, but



WILLANS SURFACE CONDENSING PLANT.

allowance is made in calculating the head for the necessary drop across the air ejector. In the case of the second, or "shunt" system, the cooling water for the condenser and the ejector water are delivered in parallel, and the ejector water is returned to the source of supply or to the circulating water suction. In other words, the circulating pump is designed for the normal head required by the lay-out of the plant, with allowance for condenser friction, and the quantity delivered is that needed for the condenser itself, plus the necessary water for the air ejector. The third, or "separate pump" type, of which the L. & S.W. installation is an example, differs from the "shunt" system only in that a separate pump is provided for delivering the air-ejector water, apart from the main circulating-water pump which supplies the condenser in the ordinary way.

In the present installation, both the main circulating pump and the ejector pump draw their water by means of a common suction pipe from the main suction culvert, which runs the full length of the engine-room. The water coming from the condenser itself is, of course, heated and passed to the delivery culvert, but the air-ejector water is returned to the suction or inlet culvert. It will be noted that in this instance the circulating pump is driven by means of a continuous-current motor, whereas the ejector pump D and condensate-extraction pump C are driven by a small steam turbine.

The vacuum attained, it will be seen, is substantially above that guaranteed, and particular attention may be drawn to the very low difference between the circulation-water outlet and vacuum temperatures. The tests were carried out after the plant had been in service for a considerable period, in the presence of the representatives of the con-

sulting engineers, Messrs. Kennedy & Donkin, and of Mr. Herbert Jones, chief electrical engineer to the London and South-western Railway Company.

Trial number.	1.	2.	Guarantees.
Duration of test	60 mins.	60 mins.	—
Load, pounds of steam per hour	68,176	68,389	68,000
Vacuum at steam inlet to condenser, corrected to 30″ barometer	28·73″	28·76″	28·5″
Corresponding steam temperature	86·6° F.	86° F.	92° F.
Condensate temperature	82° F.	82·5° F.	87° F.
Difference between condensate and vacuum temperatures	4·6° F.	3·5° F.	5° F.
Circulating water inlet temperature	58·5° F.	58·5° F.	65° F.
Circulating water outlet temperature	80·8° F.	81·1° F.	83° F.
Difference between circulating water outlet and vacuum temperature	5·8° F.	4·9° F.	9° F.
Cooling water, gallons per hour	318,000	317,600	396,600

THE DETERMINATION OF FOUNDRY COSTS.*

BY CLINTON H. SCOVELL.

AN adequate production scheme is one of the essentials for efficient foundry management. It is also the framework for the cost accounting. Upon receipt of an order for castings, at least three copies of the production order can be used effectively. One should remain in the production department and two copies should go forward to the foundry foreman, one for his file and one as an order for patterns. A summary of these orders is kept by the production clerk, classified by customers, and if desirable for production purposes, according to weight of castings or grade of metal. A daily analysis of this summary is made by the production clerk and foundry foreman, and the production for succeeding days determined. Postings are made to this record, crediting the good castings made each day and leaving as a balance the number of castings for each pattern yet to be made.

When new patterns are received at the foundry the gross weight of castings to be made from these patterns is calculated. By maintaining the record the production ahead of the plant can be closely estimated. Production orders as issued to the foundry should be given serial numbers. These order numbers can be so arranged as to indicate a customer, a class of work, a pattern, or, if desirable, all three.

The labour cost will be sharply divided between direct and indirect charges. Even if the direct charges are not further sub-divided, the total pay roll should be separated into cupola labour, moulding, core making, cleaning pattern work, and carpenter shop. In most cases there should be a sub-division of moulding and core-making labour which will show the time consumed by moulders and core makers against individual production orders. All indirect labour (except that connected with the moulding, core making, and possibly cleaning departments) should be charged to appropriate burden centres and subsequently distributed to job cost cards on the basis of pounds of good castings made. The indirect labour associated with moulding and core making will be charged from the labour distribution to the moulding or core-making burden centres, and applied to costs through the hourly burden rate of these centres.

The material charged to the cupola is the principal cost of melted metal, although the total cost of metal is composed of fixed charges on the investment in cupola equipment and raw material inventories, cupola repairs, and the labour of the cupola gang. A perpetual inventory should be maintained for all materials and supplies. This does not necessarily mean that detailed stores cards should be maintained, covering all items of supplies. But separate accounts should be kept (including freight as well as purchase price and unloading costs when kept separate) for such important items as pig iron, scrap, coke, moulding sand, &c. General supplies may well be grouped in a storeroom, for which one person should be responsible. The balances on hand may be checked individually as convenient. If various sections of the inventory are checked at regular intervals, an accurate record can be maintained, so that it is possible to prepare a reliable statement of loss and gain at the end of each period without taking a physical inventory.

It is highly advisable that such supplies as nails, gaggers, &c., be kept under stores control. Large savings have been effected by requiring the foremen of the moulding and core making departments to issue requisitions for this class of supplies, which are a charge to burden in the respective departments.

The first burden charge to each department is for rent. If the plant is rented, the rent chargeable to each department can be determined easily by apportioning the total rental paid according to the relative areas of the different departments. Where the plant is owned, the expense corresponding to rent consists of interest and taxes on the land, and interest, taxes, insurance, depreciation, and repairs, and possibly heat and light on the buildings. The sum of these charges determined for each building in the plant, divided by the available floor space in each, gives a square foot factor which can be used to distribute the rent charges to departments.

The burden charges on the equipment in the several departments will vary because of the varying cost of the equipment, affecting interest, tax, and insurance charges, and because the nature of the operations performed affects the depreciation. Charges of these various kinds are therefore based on the value and kind of equipment in each department. The sum of the rent and equipment charges are fixed whether any manufacturing operations are carried on or not.

The next charges are for power and for repairs to keep the factory in good operating condition. The power plant should be considered as an individual unit, and the cost of generating steam and power carefully determined. The cost of operating the power plant will include, besides fixed charges, such items as labour, repairs, coal, water, and supplies. Having determined the cost of power, each department using power should be charged with its correct proportion of this cost. If it is not feasible to record the power used by each department, the consumption should be estimated as closely as possible. Multiplying the number of horse-power hours used by the cost per hour the power charges against each department is determined.

In a large plant the repair department should also be treated separately, and its burden known. The original estimates on the cost of repairs in departments may be made from repair department records, or from a knowledge of the repair materials purchased, the pay roll in this department and its share of the burden. When work is done for the productive departments such work should be charged to them in the same manner as it would be by an outside company. When the charges are accumulated on the individual repair job they check the estimate in each department.

The labour cost for foremen will be part of the burden of moulding and core making, and of the pattern shop and carpenter shop if they are large enough to have charges of this kind. Cleaning labour may all be thrown together and assessed, with other general charges as a cost per hundred pounds on all the work done, but if the foundry is handling large castings which individually take several hours to be cleaned or chipped, these costs should be charged separately just as much as moulding or core-making labour, and in such cases the labour of foremen will be charged to burden as in other departments.

Some foundry executives may question the importance of dividing overhead or burden as above described. They may believe that average costs for metal, moulding, core making, cleaning, &c., are all that is necessary, and where the product is uniform a fairly good control of foundry operations may be secured in this way. However, labour costs vary widely for moulding and core making on castings of different weights and different shapes. It is the difference in labour cost that attracts attention, but it takes only a little analysis to show that there is a burden on moulding separate from that on core making. If an accurate distinction between the cost of light and heavy castings is desired it is essential to separate the burden costs as well as the labour costs, and charge these burdens in proportion to the work actually done in the respective departments and not as a flat average over the entire output.

The elements of cost in a casting are the cost of metal at the spout, and the costs of moulding, core making, and cleaning. There is overhead or burden to be reckoned in connection with all these costs, and there are certain general expenses, as for power, heat and light, and supervision, that

* Abstract of paper read before the American Foundrymen's Association, September, 1916.

must be considered and spread in an appropriate way over the product. These costs will be accumulated on the job cards for individual production orders. It is a question of discretion as to just what a production order should cover. In most foundries it will stand for a class of product, or for an individual customer's requirements, but in some instances individual castings will be made on separate production orders.

A job card should provide for the hours and amount of core making and moulding labour, the number of pounds of good and defective castings made, and a memorandum as to the loss through returns and allowances. The hours and amount of core making and moulding labour will be posted from daily labour tickets, and the weight of castings, both good and defective, from the daily production reports. A memorandum of loss by returns and allowances will be obtained from the accounting department as credits are issued.

The burden of the core-making and moulding departments will be applied to the corresponding labour charges, preferably on the basis of the productive hours already charged.

If the work is large, cleaning labour and burden will appear as separate items on the individual cards. Any charges for patterns, or machine work that may be done strictly as a foundry cost, will be accumulated on a separate cost card, but should be included on the cost-of-casting card under the heading of "Other charges."

The cost of metal at the spout as accumulated in the account set up for this purpose is to be distributed to the job cards in proportion to castings made. Some managements will desire to have the material cost of metal and the cupola operating or conversion cost separately on the production orders, but if this division is made it seems logical to go a step further and show cupola material, labour, and burden all separately. The cost of the metal and the cupola operating costs are separate, of course, on the cupola report.

Just what course is adopted in this respect will depend on the view taken in regard to defective castings, and as it cannot always be known whether castings are defective as soon as they are broken out of the sand, it seems wiser to distribute all of the cupola costs to all of the castings made. Those that prove defective have a scrap value. If this is regarded as equal to the average cost of the cupola charge the cost of the defective castings will be merely the labour and burden (and conversion cost, if stated separately) which has been incurred in their making.

The same result can be secured by distributing the cost of metal on the basis of good castings made, and distributing the cupola labour, burden, and fuel on the total weight of castings made, both good and defective. A total will be obtained as to both gross weight and amount, from which the weight only of defective castings will be deducted, if the metal cost is charged on the basis of good castings. If the metal cost is on the basis of gross weight, both the weight and value of scrap will be deducted. According to either plan, this will leave the net weight of good castings, and the total cost of both good and defective, less the scrap value of the defective castings.

To the cost, as above determined, general burden should be applied, representing miscellaneous foundry expenses, at a rate per 100lbs. The main elements of burden in a foundry are to be recognised and distributed as charges on land and buildings, and for power and repairs, but after the best possible analysis of charges of this character, and their distribution to cupola, and to the departments of moulding, core making, cleaning, &c., some general charges will remain for such items as general supervision, clerical labour, shipping, delivery, and the cost of defective castings returned from customers (less scrap value). If the product is fairly uniform and rather small, all the costs of cleaning can be conveniently thrown in the general burden on a pound basis. The expense for flasks and patterns, including repairs as well as fixed charges, is logically part of the moulding burden, but this is sometimes thrown into general burden.

The policy of different foundries will naturally vary in respect to the cost of new patterns. In a jobbing foundry where the customers own the patterns this factor will not have to be considered, but in a foundry making for its own machine shop it will be considered part of the foundry cost. The general upkeeep of patterns may fairly be included in moulding burden, but the cost of new patterns should be accumulated on individual pattern orders, even if the final charge is to an expense account. Patterns are an asset to a certain extent, and if a foundry is rapidly increasing its line it is logical to increase the asset in patterns, but after a line has been fully established an increase in the assets on account of patterns should be made very cautiously, and practically all expense of this kind charged as maintenance.

To complete an adequate cost and accounting plan for a foundry, provision should be made for summarising various records. The distribution of labour and materials and also the development of burden has already been explained. The total cost of the cupola will be distributed to individual production orders or job cards, according to one of the two plans outlined, and the total will be a credit to the cupola account and a charge to individual orders. A summary of the production orders in respect to labour and departmental burden will provide credits to the respective labour and burden accounts, and the total cost of the finished castings will be charged to an account called "Cost of Goods Sold," by individual customers if immediately shipped, or be transferred to a machine shop inventory. The foundry cost cards should provide for a convenient posting of shipments (weight and cost value), and to carry forward the remaining inventory to the operations of the next period. A few foundries maintain a stock of clean castings that have not been machined, but this is almost uniformly for the benefit of the machine shop rather than the foundry, and the value of such raw castings is much better transferred to the raw material inventory in the machine shop rather than carried as inventory of finished work in the foundry.

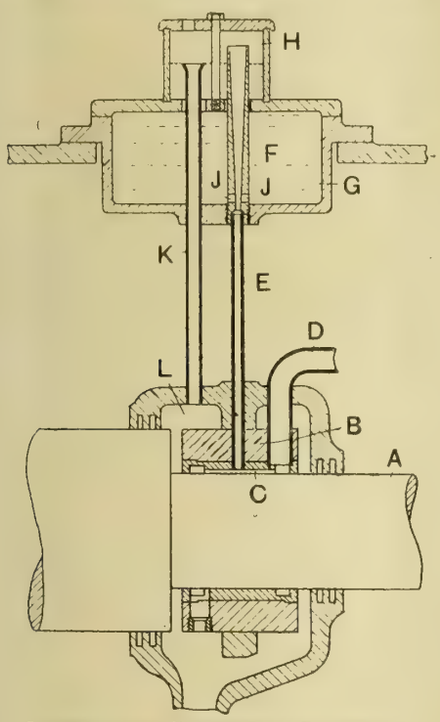
On continuous jobs, such as work for a regular customer, or on any special work that is not finished in the month in which it is started, there will be material, labour, and burden costs in the succeeding period, in addition to those brought forward from the previous period. The balances, both weights and cost values, determined at the end of each period (month or four weeks) are an inventory of work in process, and the total of the balances on the job cards should agree with the controlling account in the general ledger. This book-keeping agreement should be established as a matter of course every period, and a physical inventory should be taken and compared with the job cards from time to time as may be convenient, so that the management may be sure that the values and the weights are actually on hand. Upon each cost card there should be provision for such information as the selling price, cost of the goods sold, gross profits, loss on returns and allowances, and net profit. These items should be proved, by means of summaries, with the controlling accounts in the ledger.

LUBRICATION OF PRESSURE-FED BEARINGS.

THE accompanying sectional view shows a supplementary lubricating arrangement for bearings to which oil under pressure is normally supplied, the invention of the Ljungström Turbine Works, of Finspong, Sweden. In this arrangement an oil reservoir placed above the bearing is by means of a branch pipe connected with oil grooves in such a manner that oil is pressed up into and fills the reservoir during the time the oil supply to the bearing takes place, but automatically is led to the bearing and lubricates same when the oil supply ceases. Referring to the illustration A indicates the shaft and B the bearing. The bearing is provided with longitudinal oil grooves C, and is connected with a pressure oil pipe D, through which the oil under pressure is supplied to the bearing from the oil pump (not shown). A branch pipe E of comparatively small diameter is led from the bearing from the grooves C to a nozzle F; for example, a diffuser that is placed in an oil reservoir G above the bearing. The nozzle has its outlet into an oil cup H above the reservoir G, so that the volume of oil pouring over the edge of the nozzle can be seen. The nozzle is further provided with one or several openings J near the base of the reservoir G. For leading the surplus oil back, for example, to the oil pump there is provided an outlet pipe K, the upper end of which is at a suitable height in the cup H below the level of the top of nozzle F; this pipe by means of a groove L in the bearing casing communicates with the oil pump.

The arrangement works in the following way: When the oil

pump is started and oil streams in through the pressure pipe D it will also be pressed up through the small pipe E so that the oil reservoir G will be filled with oil, as well as the oil cup H to the edge of the outlet pipe K. It should be observed that the oil during the time it is supplied under pressure to the bearing cannot stream back to same through the openings J, as the oil on account of the kinetic energy of the oil jet in the pipe E will pass the holes J and stream over the edge of the nozzle F. The surplus oil is by means of the outlet pipe K brought back to the oil pump through the channel L. If for some reason, for example the breaking of the coupling to the oil pump the oil supply in the pressure pipe D ceases, the supply to and the pressure in the pipe E will also cease. Oil from the reservoir G will thus pass back to the bearing through the holes J on account of its own pressure and thus lubricate the bearing



LUBRICATION OF PRESSURE-FED BEARINGS.

also when the pressure in the main lubricating pipe has ceased. This is of very great importance, especially in turbo-machinery, as in these the bearings must always be lubricated, otherwise they will be severely damaged, which in most cases will destroy the turbine. The arrangement has also the advantage, that if the starting valve of the turbine is automatically closed; for example, on sudden stopping of the oil pump the turbine bearings will still be lubricated during the whole time the turbine will need to come to rest. If the oil-pressure pipe should break, the present supplementary lubricating arrangement will also be of service.

The Journal of the Municipal School of Technology, Manchester.—We have received from the Manchester School of Technology a copy of Vol. 8 of its Journal. As the technical product of its own students in the way of type-setting and printing, the publication is in every way first class, and it is equally creditable as a record of the contributions by its students and teaching staff to the proceedings of various technical and scientific societies. The papers range over a wide area, and include one by W. C. Popplewell, M.Sc., on "The Connection between Elastic Phenomena and Slow Reversals of Stress," reproduced from the Proceedings of the Institution of Civil Engineers; a second by J. T. Hodgson on "Modern Boiler-room Practice," read before the Manchester School of Technology Textile Society; a third by Messrs. H. F. Coward, C. Cooper, and J. Jacobs on "The Ignition of Gaseous Mixtures by the Electric Discharge"; a fourth by Messrs. H. F. Coward and Brinsley on "The Limits of Inflammability of Gaseous Mixtures." Others include such subjects as "The History of Dyeing," "The Commutation of C.C. Generators and Rotary Converters," "The Determination of Carbon Monoxide in Air," "The Effect of Structure on the Strength of Cloth," &c. The journal altogether is a high tribute not only to the excellence of the work which is being performed at this leading British school of technology, but to the high standing and repute of its teaching staff.

WORKS ORGANISATION.*

BY A. D. C. PARSONS, B.A., EDWIN L. ORDE AND G. H. TWEDDELL.

PART III. SELLING ORGANISATION

BY G. H. TWEDDELL.

(*Concluded from page 338.*)

Viewpoint. It is perhaps not unnatural that the writer's views as to selling methods and selling organisation should be influenced, to some extent, by his own experience—an experience extending over many years—in the marketing of electrical machinery, turbo generating plant, &c. At any rate, the author would like it to be understood that his remarks as to selling organisation apply more particularly to this type of engineering product. His reason for this statement being that the engineering industry embraces so many different varieties and classes of work as to render it impossible to outline a selling organisation which would suit equally well all branches of the profession; it being obvious that the organisation for the sale, of say, marine engines, will differ fundamentally from that required for the sale of, say, motor-cars or sewing machines. Nevertheless, it is hoped that some of the suggestions made in this paper on organisation generally, together with the hints to selling engineers, may be of value, and capable of application in the selling forces of all branches of engineering. Further, the organisation sketched hereafter in this paper is intended to be capable of transacting business on the largest scale, not only in the United Kingdom, but throughout the British Empire. Having thus, to some extent, made the viewpoint of this paper clear, it may not be inappropriate at this point to consider the value of salesmanship, and subsequently what a comprehensive selling organisation should consist of.

The Value of Salesmanship.—The selling engineer may be considered the life-sap of any manufacturing concern, as upon the results of his activities the success of the industry largely depends. The chief object in manufacturing is to effect a profit and the source of income is contingent upon the sale of the product. The most efficient factory organisation can be nullified by poor selling. It has been said that it is difficult to over-estimate the value of a good selling engineer of long and wide acquaintance in the district in which he is to operate. The value of good salesmanship is not yet fully appreciated in this country. The fact that "salesmanship" is regarded as a science in the United States will come as a revelation to most of us. If we are to depose the Germans after the war we must radically improve our methods of sale.

In the past British manufacturers have paid little attention to their selling organisations as compared with Germany and America. Admittedly, our methods have improved during the last decade, but we are still far behind our foreign competitors. Perhaps one reason for this is due to the system that has grown up amongst certain manufacturers, who, lacking a sales organisation of their own, appoint a large number of agents on commission only to make up the deficiency. This system is, no doubt, dictated for reasons of economy, but with a few exceptions it is a mistaken policy and is not calculated to secure the best results, as it prevents the manufacturer from getting in that close touch with his clients which is so conducive to further business.

Selling Representatives.—Many manufacturers seem to think a good sales organisation consists in appointing a large number of agents or travellers on commission, and further, that in consequence advertisement is unnecessary. This is a fallacy. These agents—usually most estimable men—accept these agencies and "go on the road" without any special training or knowledge of the product they are handling, or any executive power to make a "deal" if the opportunity arises. Much, no doubt, can be said for the employment of agents, but in engineering work consulting engineers and buyers generally grow tired of interviewing representatives of this kind; what they require to see is the equivalent of a principal.

The training of a selling engineer is dealt with in a subsequent section of this paper. The author here confines himself to saying that the expert selling representative of the future, after proper training in the various departments,

* Paper read before the North-east Coast Institution of Engineers and Shipbuilders.

should be able to answer questions, to give advice, to take particulars, and, in cases of necessity, prepare an estimate and conclude a contract. Such a man may possibly cost more than an agent, but the increased results and greater satisfaction to purchasers will warrant the expenditure, and prove to be a good investment. Statistics prove that of those entering the ranks of salesmanship, only 5 per cent. succeed. Success does not come easy even with the best of equipment, and it is strange that greater stress is not laid by both employers and salesmen upon the necessity of thorough preparation for sales work. Referring to the lack of training, one American writer rather forcibly states: "It is commercially criminal for any company to provide its representatives with expense money, railroad timetables, catalogues, price-books, and practically no other qualifications except brazen nerve, and inflict these trade ambassadors upon a long suffering commercial public."

A Typical Selling Organisation.—One of the first points to be considered in a manufacturing business is the market for the product, and the best methods of reaching and holding that market. This requires a selling organisation, the nature of which depends upon the type of product to be disposed of, the area or territory to be covered, and the volume of business it is proposed to deal with. As these factors vary in every business, it is impossible to outline an organisation suitable for all classes of trade. As an alternative to outlining a hypothetical selling organisation, it may be preferable to very briefly describe an organisation with which the author is associated. This organisation is perhaps the largest and is reputed to be one of the most efficient of its kind existing.

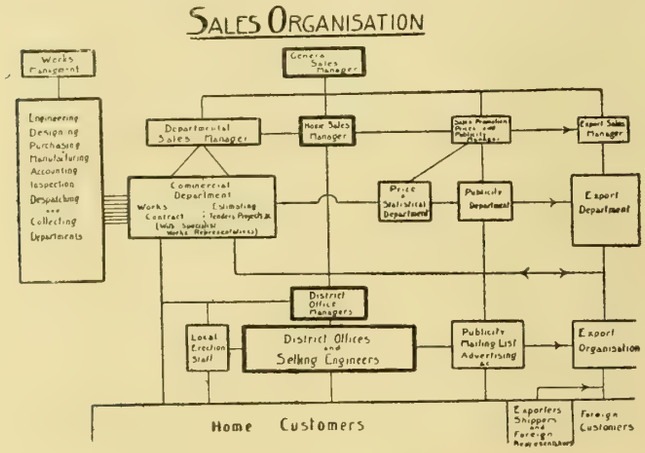


FIG. 10.

Within the limits of this paper, members will appreciate that it is not possible to enter into much detail or do more in fact than give a skeleton outline of the organisation referred to. Fig. 10 indicates the general scheme.

The Works' Commercial Department (of which the outside selling staff is a part) is under the direction of a general sales manager to whom the district office managers and special representatives report, through the manager of home sales. The Works' Correspondence Department is an integral part of the Commercial Department, and forms a connecting link between the district offices and the engineering departments. The varied and technical nature of the products to be marketed calls for high-class men as representatives, and a large number of such men, as it is essential that the relations with customers should be closer than is necessary in many other lines of business. These same conditions require that the company's representatives should live in the same district as its customers, with the result that a system of local or what are termed district offices has been created, one in each natural market of territory, controlling sufficient business to warrant its existence and so constituted as to meet the demands of what territory and the customers it has to serve. Stated briefly, there are eight district offices situated in the largest towns in the chief manufacturing centres of the United Kingdom. Similarly abroad, four district offices are situated in Johannesburg, Calcutta, Bombay, and Melbourne, and are supplemented with a number of agents located in territory not covered by the company's own offices. The export business is done through the office of the manager of export sales European business is done through the French, Italian, and Norwegian allied companies. In the case of Russia and Spain, the business is done through export agencies controlled by branch offices.

From the above it will be seen that, aided by agents and allied companies, this selling organisation covers the whole of the British Empire, including a considerable portion of Europe. The total orders secured by this force are remitted to Trafford Park and manufactured at one works employing 9,000 hands. Each district office and works selling representative is provided with two loose-leafed pocket-books; one of these is a series of price-sheets giving the latest prices of all the standard apparatus manufactured by the company. The leaves of this book are revised and re-issued from time to time by the Price Department as prices or standards change, or new apparatus is introduced. The other book contains a set of technical data referring to the standard apparatus, which is also kept up to date in a similar manner. Each district office is also provided with specifications of standard apparatus, outline drawings and diagrams of connections, &c., and a proper stock of literature descriptive of the company's apparatus, so that with these aids the district office representative is able to handle all ordinary enquiries for standard apparatus without reference to the works. When the purchaser's requirements cannot be met by means of standard apparatus, or when there is some doubt in the selling engineer's mind upon this point, the enquiry is referred to the works.

Up to this point the customer has dealt with one man who has a general knowledge of his requirements, but now his case is put into the hands of experts who have specialised in the particular commodity which is the subject of his enquiry. In the case of an enquiry covering various apparatus, it is felt that it would be disconcerting and annoying to the customer to have to deal with a number of correspondents in different departments. An arbitary rule is, therefore, made which determines that enquiries covering certain materials shall be dealt with by one Commercial Department Any correspondence with the customer or the district office respecting this enquiry will come through that department's hands, and any information required on other items in the enquiry that do not come under that department's supervision must be obtained by it from the other departments at the works, and embodied with the other information sent to the purchaser.

Each Commercial Department at the works is controlled by a sales manager who has under him a staff of correspondents and one or more selling engineers. The works' selling representatives are specialists and are called in by the district offices to assist in particular cases where special knowledge is required. For each Commercial Department at the works there is a corresponding Technical Department which gives the necessary technical information respecting the matters under consideration to the Commercial Department to transmit to the customer. Should the tender be successful and result in an order, the correspondence respecting that order is undertaken by one of the Commercial Departments at the works. A similar rule to that mentioned above determines which department shall handle the whole correspondence for any particular order. It is then the function of the Commercial Department to clear up any doubtful points and to instruct the Technical Department to put the work in hand in accordance with the customers' requirements. The Technical Departments then issue their instructions to the factory and to the Drawing Office for the carrying out of the work. Thus by easy stages from the preliminary enquiry which was handled by the district office salesman and which might comprise a great variety of articles all manufactured in different parts of the works, the required information is, as it were, sorted and distributed in a fan-like direction so that the specialised workmen who may be spending the whole of their lives in assembling one small piece of apparatus are finally brought in to satisfy the ascertained requirements of the purchaser.

Besides the Commercial Departments mentioned above, there are the Publicity and Statistical Departments, engaged in sales promotion, whose function it is to compile and analyse statistics, to produce catalogues, leaflets, and other literature describing the various manufactures of the company, and by press and other forms of advertising widen the market for the sale of the company's goods, and generally co-ordinate the

results obtained. It would raise too wide a subject to go into the benefits of advertising, publicity, &c., in a paper of this nature, though it will doubtless be recognised by all that the proper carrying out of a well thought out advertising policy is essential and of very great assistance to the selling force. A confidential bulletin is published once a month for the information of salesmen and heads of departments in order to let them know what is going on in other branches. Also a monthly house organ is published and distributed to important purchasers, giving descriptions of the work executed by the company, and articles of general interest by one or other of the experts which they employ. A comprehensive mailing list (containing approximately 30,000 addresses) is on file. This list is sectionalised into various trades to which suitable literature and special publications are forwarded from time to time, as issued. The reason for this classification is to ensure the right literature reaching the right customer; it being obviously a waste of money to send a shipyard an expensive publication, say, on electric winding-engines for collieries.

District Office Organisation.—This should be as simple as possible with one head, usually known as district manager. Working under his direction are the selling engineers, erection and clerical staff. It is hardly necessary to define the qualifications of a district manager. Business concerns usually make use of the best material available in their employ. Apart from the essential requirements of honesty, reliability, and intelligence, he should be a good judge of human nature, and have had sufficient experience to use such judgment to advantage. An engineering education and experience is usually considered an essential, and unless a man has had such education and experience, he must have all the other qualifications remarkably well developed to be able to occupy his position successfully. He should have a thorough knowledge of the apparatus he has to sell, together with a knowledge of the established customs and policy of the company.

A district office staff should be selected with care. It is the natural inclination to secure additions to the staff from the works organisation, as the knowledge of the details of apparatus brought into the office by a man from the works is of great value. Such a man also is, as a rule, only selected on account of his superior intelligence, and is promoted to the district office after a more or less extended experience in the works departments. Needless to say the clerical staff should be kept at a minimum by a proper system of keeping records, files, &c. It is unnecessary to offer any comments on this subject.

It is hoped that the above rather disjointed remarks will give a general impression of a typical selling organisation. Much detail is necessarily omitted, but sufficient has been said to indicate the lines on which it operates. Finally, it may be of interest to add the organisation described deals with a turn-over aggregating between £2,000,000 and £3,000,000 per annum, one or more of the district offices in question dealing with an annual turnover of £500,000. Some of the sales are obtained as the result of individual effort, whereas others are only secured by bringing all the salesmanship, all the engineering talent, and all the influence of every sort available in the company into play.

This section perhaps might be usefully concluded by offering one or two suggestions for the use of those who control a selling staff. Daily report forms are provided by most firms nowadays for their salesmen to fill in. These should be carefully scrutinised, with a view to counteracting any tendency upon the part of a salesman to become too set with one particular clique, to the avoidance of the more difficult and less congenial interviews. Whenever possible, an encouraging word from the director or manager should be given, as undoubtedly the present-day work of a salesman is especially hard, and the result of a succession of rebuffs is bound to reflect in the working of the man. This disappointment can usually be cleared away by a few well-chosen words of encouragement from the "chief."

Where a number of selling engineers are employed, opportunities should be given for intercourse between them. The idea adopted by some firms of calling a meeting quarterly with the directors and works departmental managers is a good one. Points possibly in dispute between the manufacturing and sales side are discussed, the future policy of the company explained, new apparatus or modifications to existing products described, and the general exchange of ideas has, in the writer's experience, been found to be extremely useful.

It is not proposed to deal with the question of the remuneration of salesmen. This largely depends upon the class of product handled, scope for business, &c. The fixed salary and expenses plus a commission on the profits above a certain figure is probably the best of all arrangements, and calculated to meet the interests of both sides.

Some men soon fall victims to the well worn cry of "price." Where there is known to be good business obtainable, provided the quality of the product is right, *i.e.*, the goods well up to market standard, backed by good service and prompt delivery, this cry should be promptly stopped. It does not require a "salesman" to dispose of the cheapest materials. The price cry is really a disease, and, like laziness, requires to be effectively dealt with. If a man does not show up to advantage in the first year of his working, a different locality might with advantage be given him.

Referring to the "service" made use of above, a point which is often imperfectly appreciated is that nowadays customers buy not merely apparatus but service, which, besides including the apparatus, covers technical advice, guidance during erection, instructions *re* operation, &c. The various items of service mentioned are not necessarily carried out by the selling staff, but by other members of the organisation. Nevertheless, carelessness or incompetence in connection with any one of the services would give reasonable ground for dissatisfaction, and prejudice the prospects of securing future business.

Training for the Industrial Side of Engineering.—The need for training and preparation for sales work for the selling engineer of the future has already been emphasized in these notes. It is here proposed to very briefly outline what is being done in this and other countries with a view to training youths for commercial and technical positions. In Germany, this training has been dealt with on a national basis. In America, a similar movement, but on different lines, has been strongly supported by engineering and other manufacturers. In Great Britain, whilst a good deal has been done for the training of the technically educated man, comparatively little has been done to provide the best possible training for youths who are to become skilled workmen.

Some works make no effort at all to train men for technical positions, and rely on recruiting their staff from other firms, a policy which in the long run is very short-sighted. Apprentices can be broadly divided into two grades, namely, those training for non-technical employment, usually styled "trade apprentices," and those for positions in which technical training is essential, usually known as "college apprentices." The following remarks may be taken as applying more particularly to the latter, as it is from this class that vacancies for the various kinds of technical employment are filled, including commercial or selling engineers.

The need for well-trained engineers for the commercial and selling side is becoming more and more apreciated by manufacturers. From the point of view of the technical student, however, there is sometimes a tendency to regard this branch of employment as suitable for one who has not pursued his college career very energetically, and for which strenuous training is not so essential as in the case of the other manufacturing positions. This is an erroneous idea, since sound technical knowledge and a considerable amount of practical training are nowadays almost indispensable for a successful selling engineer especially in the many-sided electrical industry. The technical positions in engineering manufacture referred to above are as follows: (1) The works side—comprising such positions as works and departmental managers together with assistants in the inspection, testing, estimating, and draughting departments. (2) Designers. (3) Commercial or selling engineers.

It may perhaps at first be thought that these notes upon the training for technical positions are somewhat of a digression from the subject of this paper. It should be pointed out that up to a certain point the training of youths for the manufacturing and commercial sides is identical, and it is often not until their technical and practical training has been completed that an apprentice decides which side he will take up Further, the author is seeking to indicate what the training

of the future selling engineer should be, rather than what it has been in the past.

Engineering training in this country consisted until a few years ago principally of a practical apprenticeship or pupilage course in works, and only comparatively recently has it been fully recognised that training is not complete unless it also comprises a course of technical study. In Germany, the importance of the technical side of engineering training has become universally recognised, and comparatively little importance is attached to the practical side of an engineer's training. In recent years, however, it has become a recognised practice for a young engineer to spend one year on a practical course in works. The technical course in engineering extends over at least four years.

Comparing generally the English and German systems, there is no doubt that the facilities for technical training in the latter country are much superior to those in the former; while on the other hand, as regards practical training, the English system is on quite different lines, and much more thorough. In Germany, the general education is carried further, and the complete course is finished at a much later age than in England.

In America, numerous engineering colleges and training institutions have been built and expensively equipped, most of them being heavily endowed by wealthy patrons. Attempts have been made to embody practical training on a fairly large scale with the college course; further, there are ample facilities for obtaining practical experience in works—the demand from firms usually exceeding the supply. The complete college course varies from four to six years and this may be followed by from six months to two years' practical training in works. Comparatively few facilities for evening technical study are provided in the engineering colleges.

In England, the opinion in the past has been very divided as to the best lines upon which an engineering training should be carried out. The older school clung firmly to a purely practical training, the newer school pinned its faith to theoretical training, more or less at the expense of practical training. Of late years, all engineering authorities are agreed that a period of technical as well as practical training is essential. A satisfactory training would be—after a sound, general education extending to the age of 16 or 17 years a three-year period of education in engineering science spent at a technical college, and a similar period in practical engineering work. There are various methods of obtaining the above training, viz.: (*a*) By a short period of, say, a year in works, then a technical course followed by a works apprenticeship. (*b*) By taking a complete technical, and then a works course. (*c*) By sandwiching technical and works training in varying periods.

There are advantages in favour of each of the above methods, and whilst many prefer the sandwich system, the writer favours the "college first" as being preferable. Whichever method is adopted, it is desirable that the training should terminate in the works, since a better opportunity is afforded the student for obtaining permanent employment with the firm in which he has obtained his training. The technical authorities seem to agree that it is extremely difficult for a youth who has been engaged in manual or other labour during the daytime to study effectively his technical education in the evening. Experience shows that the day student brings a fresher mind, and is better able to use his faculties than the evening student. Extraordinarily good work has been done by the latter, but this is the exception rather than the rule.

As the author's company has, during the past 12 years, trained engineering apprentices on certain well-defined lines, a brief description of their plan of training may be of interest. The apprenticeship courses are divided into two classes as follows:—

Two-year Course. — Young men of the age of 20 and upwards who have had a thorough scientific training at a University and possess an Honours Degree in engineering are admitted to a two-year course of apprenticeship on the recommendation of their college authorities.

Three year Course. — Young men of from 18 to 20 who have had a good technical education are apprenticed for three years.

Four year Course. — This applies to youths of over 16 years of age who possess a good general education and some elementary technical knowledge.

Trade Apprenticeship Course. — This covers five to seven years of work, and is open to lads of over 14 years of age. There is a school in the works at which daily instruction in trade subjects is given.

The object of these courses is to train suitable young men for the company's service in either the works, design departments, or the commercial sections, or selling organisation at home or abroad. In the two, three, and four years courses, the general procedure is the same. The apprentices are moved from department to department, as a rule, every few months, and there given every opportunity of becoming familiar with the construction and general design of the company's products, and as they show ability and as opportunity offers, they are given a trial in one or other of the commercial or designing parts of the organisation. The embryo selling engineer is eventually moved to one of the commercial or corresponding departments, and ultimately to a district office, there to take his place in the firing line as a junior with a fair prospect—with reasonable ability—of success both for himself and his company.

It will be appreciated that an engineer trained on the lines indicated above should go further on his own and his company's behalf and give greater satisfaction to the purchaser, than a man with only a superficial acquaintance with the product he is handling, and no technical or practical engineering knowledge to support him.

Essentials of Success in Salesmanship.—The selling engineer has not lacked for advice and helpful suggestions during the past few years concerning his work, as a great many articles have appeared from time to time in various publications. Notwithstanding this, too many suggestions cannot be put before him, as there is no class of literature which is so genuinely helpful. The following remarks are intended primarily for young salesmen, though it is hoped that some of the suggestions made may be of value as reminders to all of us.

The young engineer may rest well assured that there is no loss of dignity in taking up the commercial side of engineering, but a salesman failing to combine business ability with technical skill is doomed to limited advancement, if not to failure. In the more highly paid positions, men with sound commercial ability are conspicuous rather than men with high engineering knowledge. Out and out commercialism, of course, is not intended to be the standard advocated, but rather a judicious blend of technical skill, with an extensive use of true business principles. Engineering, as we know it to-day, could not exist without its commercial side. It is almost axiomatic to say that excluding replacements, new machinery is installed solely for the purpose of increasing the output, improving the quality, or reducing the cost. It is one of the first and most important duties of a selling engineer to convince the buyer that one or more of these objects are attained, otherwise the reasons for the installation disappear. The prime object of the salesman should be (1) To sell at a profit, (2) to accomplish the work required, (3) to satisfy the purchaser. If he accomplishes this, success is assured.

It is imperative that a profit should accrue from the transaction of business. This is a fundamental law of all barter and trade, though this point occasionally appears to be overlooked by some of us in our eagerness to transact a large volume of business, and it appears to our enlightened minds as though other manufacturers forget this first principle even more often than ourselves. One of the readiest and most certain means of assuring a profit, is to sell standard apparatus. This ensures the order going through without a hitch and incidentally with every chance of the delivery date being kept. Further advantages are: (1) The order is a definite request for a standard article and requires a minimum of supervision; possibility of errors are eliminated; tests are definite and predetermined; and cost assured. (2) There is no drawing work to be done. (3) The engineering expenses are reduced to a minimum. (4) The factory organisation is facilitated, tending to reduce the cost of all apparatus. (5) Finally, the chances of satisfying the purchaser are increased.

It is essential that the salesman should know the apparatus he is selling. If he knows the purchaser's conditions and the

capacity and performance of his own plant, he will feel satisfied as to whether or not his apparatus will accomplish the work required. It has been said that a salesman can make better progress in the sale of a piece of apparatus which he does not know too much about, since his faith is not shaken by an intimate knowledge of its shortcomings. This may have been well enough in the old days of salesmanship, but the selling engineer of the future should know all there is to know of the design and be trusted to take care of himself. The true art of salesmanship consists in marketing goods (it is understood at a profit) and in such a way as to ensure future preferential dealings with the customer. We are all salesmen to a degree, whether we sell machinery, our manual or mental services, or even the use of our money. Like everything else worth having, the becoming of a successful salesman requires effort and study.

With suitable training and study, the salesman can be educated and moulded, or, to use a shop expression, can be manufactured from raw material of reasonable suitableness, and the almost universal belief that "the salesman is born, not made" is largely erroneous, misleading, and discouraging. A "born salesman" with equal training may reach a higher and quicker success, and that is all. This "bornness" often entails so many infirmities of genius as to greatly modify its value. In the game of salesmanship, as it is being played to-day "bornness" untrained cannot compete with highly-trained mediocrity. This is especially true in the sale of products requiring engineering and technical knowledge. Personality is a tremendous factor in salesmanship and it can be cultivated and intensified. Success often hangs upon this one feature. The man endowed with an abundance of energy and balancing qualities will make the most successful salesman, while the man of phlegmatic temperament should turn his attention to some other calling where personality, energy, and magnetism do not count for so much. Many men fail because they have too great a love of ease, entertainment, and a good time. Their expense accounts increase, their sales suffer, and they very probably acquire habits that will result to their detriment.

The art of expression is a rare accomplishment, and one that almost any man of education can develop to a high degree. Perhaps no accomplishment counts for more in successful salesmanship than does the power of terse and lucid expression. To quote from Edgar A. Russell, the author of "Ethics and Principles of Salesmanship"—"The deeper the knowledge, the broader the culture, the keener the reasoning faculties, the stronger will be the power of expression." We can afford to systematically study to increase our knowledge, and to increase our power of expressing it to others. Balzac spent as much as a week upon a single page of his writings, Webster spent 36 years of continuous work producing his dictionary.

General business honesty is again a particular qualification for an efficient and successful salesman. Some young salesmen seem to think that a possible trick is justified, so long as he gets the order from the buyer. This policy might succeed if you had a fresh customer for every deal, but in nearly every business, and especially in engineering, you have not only to make a customer, but you have to retain him permanently and successfully, either as a company or as an individual. No business has ever progressed, or ever will progress, that is not to the mutual advantage of both parties. Personal honesty, therefore, as well as business honesty, clean living, and frankness, should be cultivated by the salesman having a desire to make a success of his business. A comprehensive knowledge of the products offered for sale has already been mentioned as an essential to success.

All men, almost without exception, like flattery. Some take it in small doses, and growl when they take it. Others will take it in large doses, and smile as it is given. Properly applied, it is a very effective medicine. A successful salesman, however, must know when to talk and when to keep still. One writer has said "A real salesman is one-part talk and nine-parts judgment." Whilst not subscribing to this statement literally, it is fairly near the truth. Most men have a hobby, and when he can be drawn out to talk that hobby, it is about the most subtle flattery that can be given to him. A characteristic which is at once the cheapest commodity, and one which pays the best profits of anything in a salesman's armoury, is the habit of respectfulness and courtesy; to this might almost be added fairness to your competitors when it is necessary or advisable to mention them or their products.

A further faculty to be developed is resourcefulness and adaptability. In the progress of a negotiation of any size the setting is liable to change between its inception and its closing. In fact it is changing every moment it is in progress, otherwise an end would never be reached. It is necessary that the salesman should be able to size it up and quickly change his tactics. Resourcefulness will enable the salesman to know when to pursue the policy he has been following, and when to change it. He must be quick to adapt himself to any circumstances which may arise throughout the negotiation. It was once said of one of the most successful salesmen that he was quite equal to running a Methodist prayer meeting in the early evening, and go out with the boys later at night, and be the leader all the time. Quick personal adaptability of this kind is not exactly recommended, but a successful salesman must be able at all times to adapt himself to the people with whom he is dealing.

To sum up, if the candidate for success in the sales field lives a clean life, has a knowledge of human nature, and ability to recognise it when he meets it, a knowledge of the material he is handling and its application, has honesty, energy, courtesy, and enthusiasm, he may rest assured that he will quickly develop into a successful and efficient salesman.

THE FUTURE OF THE MARINE OIL ENGINE.

BY JOHN F. WENTWORTH.

THE oil engine unquestionably has a great future before it, but in order that this future may be realised in the actual commercial development of this type of motive power certain points must be carefully kept in mind. The first point to consider is that the oil engine differs from the "gas engine" only in its fuel and means of using this fuel. There is no thermo-dynamic theory underlying this engine, which is different from the gasoline (petrol) engine, other than the points brought up by the use of such a fuel as is practical for use in commercial vessels in competition with coal-burning vessels. Consideration will first be given to the matter of economy, then the fuel which will make this economy possible, and lastly the fuel valve which will make it possible to use this fuel.

Economy.—In considering the matter of economy, the relative merits of the two- and four-cycle types of engine are matters of prime importance. It is generally conceded that the two-cycle has about 10 per cent. lower efficiency than the four-cycle. This means that power for power the two-cycle uses 10 per cent. more fuel than the four-cycle. This comes about probably from the frictional loss in the scavenging cylinders, and from the fact that a part of the expansive energy of the fuel is lost through the open ports at the end of the working stroke. It is not the purpose to take up this controversy at this place. This difference in efficiency exists, and it must be offset by some other feature such as compactness, lightness, or cheapness of manufacture, if the two-cycle engine is to be adopted.

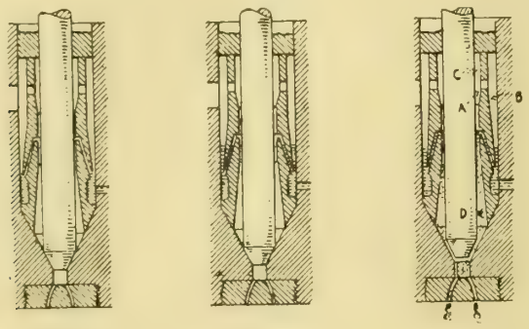
One point of prime importance in both types of engine is the fact that about 10 per cent. of the brake horse-power is consumed in the air-compressors for high-pressure air. This is a loss which can be properly considered here. The prime use of this high-pressure air is to feed the fuel into the cylinder. If it be possible to cut down this loss by 50 per cent., then a saving of 5 per cent. of the fuel used in either type of engine can be accomplished. It is certain that a part of this saving at least can be made by using hot injection air for fuel feeding. In the beginning of this work the fuel valve was water-jacketed very carefully. This results in assuring that the injection air shall be very cool. The question of how far this should be carried is one of the points for manufacturers to consider and for prospective purchasers to investigate, since it has a very direct bearing upon the performance of the engine.

Another point affecting the economy of the engine is the low mechanical efficiency of the oil engine. This is due no doubt to the high pressures used in the present types of engine. If it be possible to reduce these present pressures, then the mechanical efficiency will rise, with the result of greater profits to the purchasers of this type of plant. That this is possible has been demonstrated by actual experiments

with heavy fuel fired in a cylinder where the pressure was not over 150lbs. in place of the 500lbs. at present commonly used in the oil engine.

Fuel.—Recently the agent of an oil engine advised in the engineering press against the use of the extreme low grades of fuel for the oil engine. My purpose is to try to show the folly of such advice. We see the world to-day trying to catch up with the demand in the matter of gasoline (petrol). It is my purpose to warn prospective purchasers of oil engines from being caught in the position of the automobile users. The gas oil is a refined product. It is not used in steam plants for fuel. In other words, it is the gasoline (petrol) of the oil engine. When gasoline (petrol) was first used for power purposes it was a by-product from the production of kerosene (paraffin). For years it was reasonable in price till the rapid production of gasoline (petrol) engines has caught up with the production and made the price almost prohibitive. The same will happen with any fuel which is of use only for the oil engine. The oil engine which cannot be caught by the high price of fuel is the engine which uses the same fuel as that used by the steam plant. Users of oil engines can only rest assured of the future so long as they are using the same fuel which is being used by the steam plants. Owing to the fact that the steam plant has an efficiency of around 10 per cent., the oil engine with its 30 per cent. efficiency will be safe from a pinch in price of fuel so long as this condition exists.

The only sensible difference between the gas oil and the steaming oils lies in the viscosity. This makes it more difficult to atomise. Would it be worth while for the motor ship



Injection stroke completed. Valve just closed. | Fuel pump stroke completed. Valve still closed. | Working stroke. Valve open, feeding fuel.

HESSELMAN FUEL VALVE FOR OIL ENGINES.

to buy steaming oil and refine it or treat it so that a form of gas oil could be made? It certainly would be, provided the expense of the operation is not prohibitive. This process simply calls for the fuel to be heated. Oils of an asphaltum base, which is the class to which the steaming oils belong, increase their Baumé 1° for about every 15° rise in temperature. This means that a fuel of 19° Bé., which would be a very low-grade fuel, if heated to about 300° Fah. will have a Baumé of 33°. This will compare very favourably with gas oil. After this heavy oil has been treated in this manner it will in every way be the equal of gas oil so long as this temperature has been maintained.

What is the present advantage in the use of this heavy fuel? The fuels have practically the same calorific value per pound. Fuels are bought by the bulk. Oil of 19° Bé. has a specific gravity of 0·94. Oil of 33° Bé has a gravity of 0·85. The difference in price between steaming oil of 0·88 gravity and gas oil of 0·85 gravity is about 15 per cent. in carload lots. The difference in the case of the heavier fuel is much greater. Besides this difference in price there is the additional advantage due to the fact that a gallon of the heavy fuel will do more work than the same amount of light fuel.

This shows an advantage of over 50 per cent. at present, besides the assurance against a pinch in price later. Is it worth taking a little trouble for? Can you buy an engine which will use this fuel? It certainly is worth the trouble to use this heavy fuel. You can get the engine if you ask for it. Naturally the builder will advise against this type of engine because its construction is more difficult in all parts pertaining to the fuel handling. No oil engine manufacturer will deny that he can build this type of engine. If he does, go to a builder who can. There are engines in operation to-day which are using this type of fuel. An engine bought and installed in the municipal plant in Palo Alto, Cal., has been running on this oil for a year with good results. The fuel used in this engine is of 15° Bé.

Fuel Valves.—The various types of fuel valves have been so often described that their elements are familiar to all. It will be more to the point to consider what to look for in a good fuel valve. The fuel valve to handle the oil must be equipped to handle sluggish flowing oils. This type of oil can be improved by heating, but at the same time the valve should be the best possible. In the original type of fuel valve the oil was delivered into a space broken up by a series of baffles. When the fuel valve was unseated, the air rushing through this tortuous passage was able to break the oil up and deliver it in a fine spray. To secure perfect results with a valve of this sort using the heaviest grade of fuel is very difficult, if not impossible.

The fuel valve is the oil engine's carburetter. It must be perfectly reliable. To be able to get this result, it is only needed to study the action of the familiar nasal atomisers. They can draw free flowing oil and deliver it in the form of a suitable spray. If one takes a standard nasal atomiser and fills the glass with gas oil, it will be found that a perfect spray can be obtained. If we substitute in the household article heavy oil in place of the light oil, it will be found that no spray can be produced. What is the reason? Simply, that the syphonic action is not strong enough to lift the heavy oil. This suggests to us that any fuel can be sprayed if we force a stream of fuel into a stream of high-pressure air at right angles to this air. In this way the action is absolutely positive.

One fuel valve of this type, the Hesselman fuel valve, is at present on the market. In the figure showing the operation of this valve the different parts of the passages are lettered. As long as the valve is closed the air pressure at A, B, and D is equal. As soon as the valve is unseated, owing to restricted passage from A to D, while the pressure in A and B is equal, the pressure in D is reduced. The available pressure forcing the fuel into the stream of air will depend upon the size of the passage into the cylinder, the size (cross-sectional areas) of the restricted passage, and whether the fuel passage from B into the restricted passage between A and D is near to A or to D. The only objection to this valve is that once it is built it is suited to a certain condition by the proportions of valve. The fuel is delivered at right angles to a moving stream of air, and it seems reasonable to think that any fuel can be used in a valve of this type. This valve does not act on the siphon idea, but on the principle of a positive pressure behind the oil forcing it into the stream of air. This element of positive pressure behind the fuel seems to be the most desirable element in the fuel valve.

Summary.—Finally, in considering different types of engine for installation, do not be misled by the great saving at present in the use of any type of oil engine. Remember that fuels which are cheap now may be dear before your engine is scrapped. Demand an engine which will use the sort of fuel which is used under the steam boilers. If you decide to install a 2-cycle engine, remember, that at the start you are giving a 10 per cent. handicap to your competitors who use a 4-cycle engine, and make the builder show you very clearly how you are to make up this 10 per cent. handicap. When these questions are settled to your satisfaction you cannot be far wrong in your selection of the engine for your fleet.—"International Marine Engineering"

North-east Coast Institution of Engineers and Shipbuilders: 1916 Scholarship.—The 1916 Institution Scholarship has been awarded to Edmund Victor Telfer, an apprentice in the service of Messrs. Wm. Gray & Co., Ltd., West Hartlepool. The Scholarship is valued at £50 per annum, and is tenable for two years. The Council, believing that the time has arrived for making the subjects of the Institution's Scholarship Examination more comprehensive than hitherto, have decided that the syllabus of future examinations shall be: (1) English; (2) English history and geography; (3) Latin, Greek, French, or German (one of these four); (4) extra mathematics; (5) and (6) either experimental science and mechanics, or any two of the following: chemistry physics, mechanics.

STEAM-FLOW MEASUREMENT.*

BY ERVIN G. BAILEY.

THE accurate measurement of the flow of fluids is one of the most important problems facing the mechanical engineer to-day. The turbine, boiler, and mechanical stoker have been materially improved in their design, both as to size and efficiency, but much still depends upon the method of operating these large units. The operating engineer cannot get results when working in the dark; he particularly needs to know the steam output from the boilers, the condition of the fuel bed, the air supply to the furnaces, and the steam consumption of the turbines. Methods of determining the kilowatt output of the latter have been in satisfactory use for a

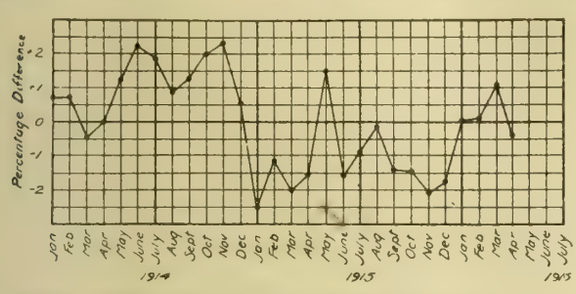


FIG. 1.—COMPARISON OF STEAM METER READINGS AND ACTUAL WEIGHTS OF STEAM.
Abscissas give percentage differences in meter readings from actual weights.

number of years. Electricity is comparatively easy to measure, and we find the switchboard supplied with all kinds of instruments for this purpose. There is just as much need for the corresponding measurements of the flow of steam and gases.

Methods of Measuring Pressure Difference.—It is desirable to go a step further than merely to measure these rates of flow, and show in addition the relation between two or more interdependent qualities which enter into the operation of a steam boiler or prime mover. Seven years of experimenting, which involved the use of more than 50 steam-generating or steam-using units, have produced many interesting results along this line, but the present paper will be confined to the measurement of steam flow, as this is really the crux of the whole question. Few problems have been more baffling to the mechanical engineer than the accurate metering of steam in large quantities. It is necessary to use the "flow" principle; that is, to produce a pressure difference which varies in a definite and known relation to the rate of flow, and then to measure accurately this pressure difference in terms of weight of steam. There are only two fundamental principles that have been used to obtain the pressure difference, viz., "impact" and "change in velocity." The "impact" principle is used in the pitot tube with its various modifications, and the vortex and metering bend also belong to this class. The "change in velocity" type covers the venturi tube and the orifice.

We do not usually think of the orifice as being of the same basic principle as the venturi tube, but the two are practically identical when the orifice is used in a pipe and the pressure connections are made at the proper place. The pressure difference produced in both cases is caused by the increased velocity and the corresponding change in the static pressure between two different positions along the pipe where the flowing stream has different areas. The exact area and location of the smallest section of the stream on the downstream side of an orifice may not be quite as tangible a thing to see and measure as is the throat of a venturi tube, to which it corresponds; but experiments have proven that it is none the less a perfectly dependable function of the opening in the orifice plate. With high initial velocities the pressure difference is largely restored in static pressure within four pipe diameters beyond the orifice, so that the net loss in head caused by the orifice may not be more than 25 per cent. of the head available. This compares very favourably with the best design of venturi tube, where the net loss is about 15 per cent. of the total venturi head.

* Abstract of paper presented at a meeting of the Boston section of the American Society of Mechanical Engineers, May 23rd, 1916.

Pitot-tube and multi hole nozzles of various designs and modifications were used exclusively during the first two years of experiment, but were entirely abandoned for reasons explained later. The venturi tube was at first considered to be the only available substitute, but the expense of changing large steam pipes, in addition to the cost of the tube itself, made this prohibitive for very general use. The orifice was taken up and the following important points were considered in working out a suitable design: (1) The orifice plate must go in between a pair of existing pipe flanges. (2) It should not thicken the joint so as to throw the flanges out of parallel. (3) The metal used should perfectly withstand all corrosion and abrasion. (4) It should be capable of easy installation.

Type of Orifice Adopted.—The initial design consisted of a $\frac{1}{32}$in. Monel metal plate having corrugations on its outer edge to make its own packing the same as a corrugated copper gasket, and having a round concentric hole smaller than the pipe diameter. But what coefficient to allow in calculating the size of the orifice of a given pipe diameter, steam density, and rate of flow was the big unknown. The importance of testing the orifice to see if it would maintain a constant factor over long periods of time was of more importance than to know the exact factors under all conditions, consequently some guesses as to the coefficient were made and several orifices were put into

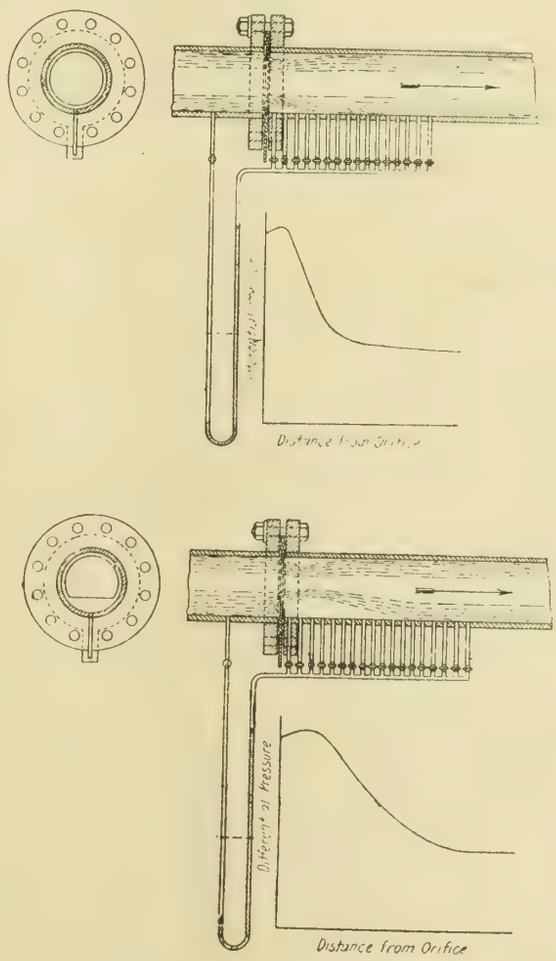


FIG. 2. EFFECT OF LOCATION OF PRESSURE CONNECTIONS.

experimental use in places where the service was continuous and severe.

It may seem that the early experimenting could have been done with most anything and a satisfactory design worked out later, but too often some practical consideration necessitates a decided change in design which upsets all the previous results It is much better to get a good working design and learn whether the device will keep on working and maintain its accuracy, before any extensive scientific tests are made to learn definitely what physical laws are involved in its use. One of the first orifices of this type was put into a 15in. pipe supplying steam at 200lbs. pressure and 150° superheat to a 15,000 kw. turbine in the L St. Station of the Edison Electric Illuminating Company of Boston, where the rate of flow averages more than 150,000lbs. of steam per hour. The

only flange available was at the inlet to the turbine strainer, about 6ft. (or five pipe diameters) beyond a 90° bend of 6ft. radius. The testing department of the Edison Company have made weighed water-rate tests of this turbine each month since this orifice was installed in December, 1913, and results from this orifice have been obtained at the same time.

Data of Tests on Experimental Orifice Meter.—The percentage differences between the weights and orifice meter results are plotted in Fig. 1. Twenty-eight tests have been made extending over more than two years, and during that time approximately 1,000,000 tons of steam have passed through the orifice. It will be noted that the greatest difference is 2·51 per cent. and that the majority are within 1 per cent. The device for measuring this pressure difference was not of the latest and best design. It is shown conclusively that there is no appreciable change in the orifice factor over this period. This is also borne out by the measurement and appearance of orifice plates replaced by others of larger capacity after a year or more of service, none of which shows any corrosion or wear whatever.

The main object of the Edison tests is to determine the water rate of the turbine, the orifice data being secondary, and it is customary to make all tests at approximately the same load, but this does not detract from the value of these results in proving the continued accuracy of the orifice over long periods of time. Other orifices were put in from time to time under various conditions where weighed-water calibration data could be obtained at capacities most frequently met in

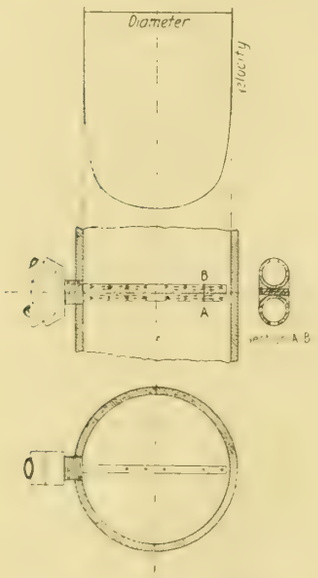


FIG. 3.—EXPERIMENTAL MULTI-HOLE NOZZLE WITH SIDE OUTLETS.

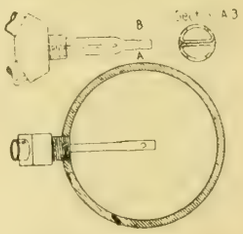


FIG. 4.—SINGLE-HOLE NOZZLE.

practice. The coefficient of discharge did not appear to be as constant for different ratios of orifice to pipe diameter as it had been hoped that it would. The indications were that the orifice was fundamentally correct, and the discrepancies encountered were only through lack of sufficient knowledge relating to details. The general trend of the data up to this point was that the coefficient of discharge increased with an increase in the ratio of orifice diameter to pipe diameter, with no obvious reason why it should. In cases where the area of the orifice is large compared with the area of the pipe, the velocity of approach is an important factor, but even taking this into consideration, the net coefficient of discharge increased with the orifice area. This same fact has since been brought out by Hickstein, who practically followed the results obtained in Charlottenburg some years ago. These two experiments dealt with natural gas and air only, and, unfortunately, the pressure connections were located at such great distances from the orifice plate that they could not possibly be duplicated in but very few steam pipes, where there were long straight runs.

Location of Pressure Connections.—The question which came up in this problem, that had never been thoroughly investigated to our knowledge, was the location of the pressure connections on the upstream and downstream sides of the orifice. It was felt that this was a point which should be thoroughly investigated, consequently, at the writer's suggestion, Prof. Judd, of Ohio State University, started some experimental work along this line and some of his results were presented in a paper at the New Orleans meeting of this year under the title of "Experiments on Water Flow Through Pipe Orifices." The important points brought out by Mr. Judd's data are: (1) The coefficients of the orifices tested are substantially constant at all rates of flow for any one set of pressure connections, regardless of their location with respect to the orifice plate. (2) The location of the pressure connections is of vital importance with the higher ratios of orifice to pipe diameter with round concentric orifices, due to the restoration of static pressure. (3) The use of specially designed orifices of other shapes than round and concentric permits the downstream connection to be far enough away to clear any flange, and also allows more latitude in the location of this connection without endangering the accuracy.

The last two points are clearly illustrated in Fig. 2, which shows a diagrammatic arrangement of the experiment and the plotted curve representing the pressure difference as measured between the upstream connections and the several downstream connections located at ½in. intervals from the orifice plate. It is evident from the round concentric orifice of relatively large diameter in the upper view of Fig. 2 that the action of the fluid on the downstream side of the orifice is practically identical with that in the venturi tube. The point of highest velocity is at the "vena contracta" just beyond the orifice plate, and the static pressure is the least and the pressure difference the greatest at this point, which corresponds to the throat of the venturi tube. The active stream extends beyond this point, and as its velocity is thereby reduced the static pressure is partially restored, and the pressure difference correspondingly diminished. As high as 77 per cent. of the pressure difference is restored in some cases.

It seems that the orifice acts merely as a forming tool to direct the active stream into a natural venturi shape, and at the same time gives just as dependable results. In fact, it appears to give more dependable readings than a venturi tube when placed close beyond or in front of bends or other disturbances. Similar orifices put in under the conditions given below gave the same coefficient within 1 per cent. when calibrated by actual weight tests.

Conditions of Orifice Installations giving same Coefficient within 1 per cent.

Size of pipe, inches	Fluid measured.	Straight run on upstream side, pipe diameter.	Conditions on upstream side of straight run.	Straight run on downstream side, pipe diameter.	Conditions on downstream side of straight run.
15	Steam	5	90° bend	none	Turbine strainer
8	Steam	1½	90° bend	none	Turbine strainer
6	Steam	3	90° bend	none	Gate valve
6	Steam	20	Gate and globe valve	20	Orifice
5	Water	59	Elbow	56	Orifice
4	Steam	6	Outlet of 4in. tee	none	Gate valve

Unsuitability of Pitot Tubes and Nozzles for Measuring the Flow of Swirling Fluid.—The writer believes that a helical or corkscrew motion of the fluid following a bend or similar disturbance is very common and prevents any satisfactory results being obtained from the use of pitot tubes, multi-hole nozzles, or venturi tubes, while the orifice seems to give the same coefficient as if in a long straight run of pipe. To illustrate this the following interesting experience is given: It was desired to measure the steam output from some 250 h.p. boilers having 8in. steam outlets which gave a very low steam velocity. The boilers were standard two-drum Babcock and Wilcox with the 8in. pipe rising from the manifold with a 90° bend and then about 3ft. of straight horizontal run into a gate valve adjacent to the header. At first a multi-hole nozzle, similar to that shown in Fig. 3, was located about 1ft. in front of the gate valve, and upon calibration it was found that the reading was about 15 per cent. lower than would be expected. At first it was assumed that the highest velocity was not in the centre of the pipe, but was shooting above the nozzle as a result of the 90° bend. Traverse work in steam pipes from boilers was not attempted, owing to the fluctuating rate of steam flow and the difficulty of handling adjustable tubes in high-pressure steam lines. A single-hole nozzle, like that shown in Fig. 4, was then tried, and a rather unexpected set of results obtained; for during the night time, when the load on the boiler was very light, it was found that this nozzle gave very nearly the same factor as applies to a long straight run of pipe, but as soon as the load came on in the morning, instead of the steam-flow pen starting up, it would drop. If

the load was sufficiently increased it would come back to the same reading given on the night load, or a little higher, but never did it go anywhere near as high as it should. Some calibration work under the heavy-load conditions showed that this single-hole nozzle gave results as much as 85 per cent. low.

In seeking an explanation all available literature on the subject was examined, and it was found that the paper of Gregory and Schoder (Trans. Am.Soc.M.E., vol. 30, 1908) gave practically the only data pertaining to traverses of pipe lines in and near a bend Some very peculiar flow curves were shown in this paper with practically no comment, but by plotting these flow curves on pieces of paper and pasting them at right angles to each other as the traverses were made and stringing them on a bent wire, it was very evident that a swirling motion was taking place, which resulted in a higher velocity near the circumference of the pipe than existed in the centre. This coincided with our experience, because the single-hole nozzle showed the velocity in the centre of the pipe to be normal at low velocities, but very much below normal at velocities which might be expected to produce the helical motion.

To prove this beyond doubt, the next step was to put in a single-hole nozzle, or the equivalent to a pitot tube, with the openings near the circumference of the pipe. This was done, and it was found that a very high velocity existed within ½in. of the circumference of the pipe when the boiler was steaming at 50 per cent. or more of its rated capacity. This experience killed all faith in the pitot tube and any other type of nozzle for use in steam pipes where there was any possibility of helical or swirling motion. Orifices were installed in these boiler connections at the inlet to the gate valves with very accurate and satisfactory results. The gradual contraction at the inlet

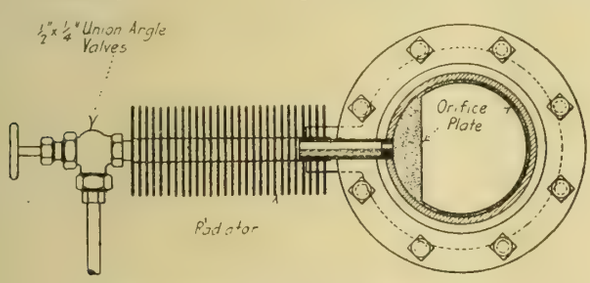


FIG. 5.—SEGMENTAL ORIFICE AND RADIATOR IN HORIZONTAL PIPE.

to a venturi tube would have no tendency to destroy the helical motion, and its angular velocity would be greatly accelerated in the throat, thereby producing a centrifugal force against the piezometer holes and giving an erroneous pressure difference. The more sudden contraction in the orifice and its downstream pressure connection being entirely away from the active stream, are undoubtedly responsible for the satisfactory results from its use.

In addition to the fact that the multi-hole nozzle did not give a true average in the instance referred to with the helical motion of steam, it also failed to maintain a constant factor even in long runs of straight pipe. The type of nozzle used in these experiments is shown in Fig. 3. This was made by driving two pieces of $\frac{5}{16}$in. phosphor-bronze tubing into a plug having a $\frac{3}{4}$in. pipe thread to be screwed into the side of the steam pipe. Regardless of the size of pipe, the upstream tube was drilled with eight $\frac{3}{32}$in. holes, equally spaced across the diameter of the pipe. The downstream tube was drilled in the same manner, so that it got the reverse effect instead of being a true static. The side outlet holes shown were used only for high velocities. The theory of this multi-hole nozzle is not based upon very sound premises, for in the case of a normal flow in a long run of straight pipe with the higher velocity in the centre, it is obvious that the dynamic force against the holes near the centre of the pipe will be greater than that against the holes near the side, therefore steam will enter the centre holes, divide, and run in both directions through the $\frac{5}{16}$in. tube and be forced out against the flowing stream through the holes near the side of the pipe. The net result, in so far as pressure or pressure difference is concerned, will, therefore, be a function of the relative area of these holes as compared with the area and length of the tube in which they are drilled, together with the spacing of the holes along the tube with respect to the diameter of the pipe. Considerable experimenting was done with this type of nozzle in various sizes of pipes, and its coefficient was found to vary between 1·19 and 1·21.

Early in our experience some very high velocities were encountered in the case of 500 h.p. boilers provided with 5in. steam pipes, as the boilers were frequently operated at 220 per cent. or more of their rated capacity. The velocity head that would be produced by the multi hole nozzle, as shown in Fig. 3, with only the upstream and downstream holes would have exceeded 7in. of mercury, which was beyond the capacity of the recording device being used, and it was, therefore, necessary to minimise this pressure difference in some way. It was first decided to drill by-pass holes between the upstream and downstream tubes of the nozzle, but this was never tried because the tubes were not always exactly the same distance apart, and in drilling through the spacer and brazing material which filled the space between the tubes, it would give the equivalent of a long tube of small diameter with variable and undetermined length. Therefore, the holes were drilled in the sides of both the upstream and downstream tubes, which would be top and bottom in an horizontal pipe. Such a tube is shown in Fig. 3. The size of these outlet holes was varied according to the velocity to be contended with and the pressure difference desired.

A large number of calibrations was made with such multi-hole nozzles in 5in., 6in., and 8in. pipes, with outlet holes varying from a No. 60 drill up to a No. 47 drill, in which case the coefficient was brought down as low as 0·68, as against 1·20 with no side outlet holes. Continued experiments with these multi-hole nozzles showed their vital weakness to be in a change in coefficient, resulting from the accumulation of sediment around the edges of some of the holes, thus reducing their area. In many cases some of the holes were entirely plugged. In some steam pipes this sediment accumulated very rapidly, so that no dependable results could be obtained over any reasonable length of time. Even the simpler types of nozzle, where there were no outlet holes, and only those pointing directly up and down stream, produced the same trouble, for sediment would accumulate around the holes at the radiator end of these tubes and a higher pressure difference was produced, due to the relatively greater effect of the holes near the centre of the pipe. In time, the centre would become partially or completely plugged, in which case the coefficient would again approach normal, and then it would decrease when only the holes in the low-velocity zone at the farther side of the pipe were left open. In the latter case the meter would read low. Larger holes minimised or delayed the change in the factor, but they did not prevent it.

Maintenance of Equal Water Levels in Connecting Pipes.—In measuring the comparatively small velocity heads or pressure differences available, it is necessary that the recording instrument casing and the connecting pipes be completely filled with water and its level be maintained equally in both pipes, otherwise a false differential due to the unequal water head will result. At first it was thought best to provide large reservoirs in each connection and on a level with the point where the steam line is tapped, so that any displacement caused by a movement of the mercury in the U-tube or recorder mechanism, due to a change in the rate of flow, would not materially lower the water level in one reservoir. The equal volume of water that was forced into the other reservoir from the recorder drained back into the steam pipe. This arrangement required excessively large reservoirs to prevent serious lag with a variable rate of flow. It was realised that, regardless of the size of the reservoir, accuracy in following a variable rate of flow was dependent upon the rapidity with which steam could be condensed in the reservoir to replace that which had been drawn out. By providing sufficient radiating surface the size of the reservoir was of secondary importance, so the type of radiator shown in Fig. 5 was tried and found to be very satisfactory. The radiator consists of a piece of ½in. extra-heavy copper pipe, plugged on the end which is screwed into the steam pipe, with a ¼in. hole drilled in the top half of the plug. A number of specially designed washers or fins, 4in. in diam. and $\frac{1}{16}$in. thick, are pressed on to the ½in. pipe and give ample radiating surface to maintain substantially equal water levels in the connecting pipes, regardless of fluctuations in the rate of flow.

The relation between rate of flow and pressure difference substantially follows the $V^2 = 2gh$ law for the orifice as well as the pitot and venturi tubes. This means that for a rate of flow that is 10 per cent. of the maximum allowable capacity, the pressure difference available to operate any U-tube indicator or other device is only 1 per cent. of the maximum.

(*To be continued.*)

CYLINDERS FOR SINGLE-ACTING INTERNAL-COMBUSTION ENGINES.

FIGS. 1 and 2 show two designs of cylinders for single-acting internal-combustion engines, the invention of Messrs. Sulzer Bros., of Winterthur, Switzerland. In both designs the cylinder has the starting valve and fuel injection valve arranged side by side and the inner cylinder or liner, removable in the direction of the crank, is provided with an upper cylindrical extension to receive the valves, the cylinder liner and the extension being in one piece. In this way uneven strains are, it is claimed, prevented, and the whole inner cylinder or liner can be machined on a lathe.

Referring first to Fig. 1, which is a longitudinal section and plan of the cylinder of a 2-stroke Diesel engine, A indicates the inner cylinder or liner, B the casing, C the top or cover of the casing, and L the piston of the engine. The liner A is provided with ports D and E for the escape of the combustion gases, and the admission of the scavenging and charging air respectively, as well as with an opening F with a sleeve or extension M for accommodating the fuel valve N and the starting valve O which are

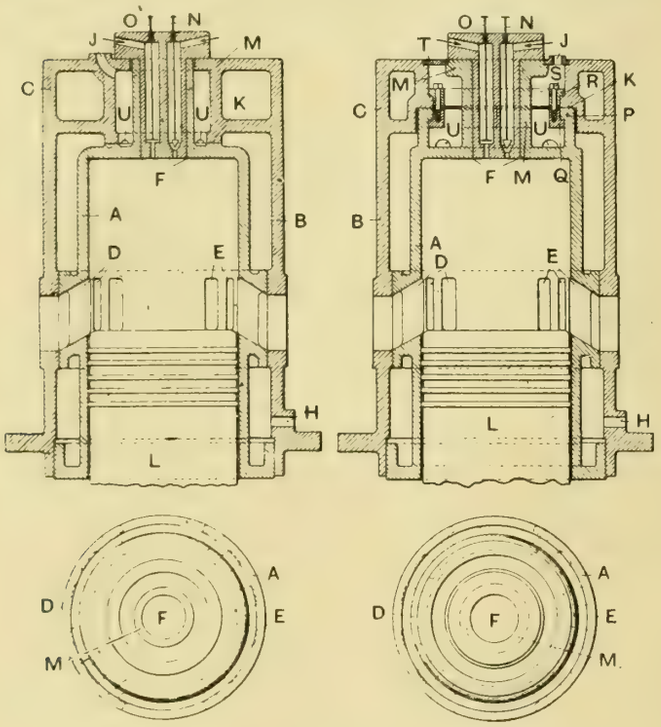


FIG. 1. FIG. 2.
CYLINDERS FOR SINGLE-ACTING INTERNAL-COMBUSTION ENGINES.

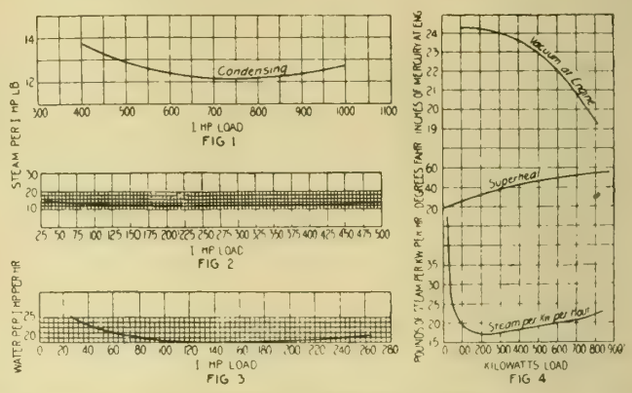
arranged side by side. The outer cylindrical casing B forms with the liner A a cooling jacket. The cooling water is admitted at H, passes through the holes U and escapes again at the top through the openings J. The inner cylinder or liner A is introduced from below into the casing B its upper end bearing against an annular flange K on the underside of the cover C. The liner A and its cylindrical extension M are formed in one piece. In the construction shown in Fig. 2 the liner A with its extension M are held up against the flange K of the cover C by means of an internal flange P, a sectional ring Q, its counter ring R, and studs S. The part T is an annular cover plate closing the water jacket round the extension M. As will be seen from the drawings in each construction the liner and its extension can be machined not only inside but also outside on a lathe. This form is further advantageous, as it enables the liner to withstand the heating and strains caused by the combustion gases.

THE UNIFLOW ENGINE.*

BY W. TRINKS.

THE trend of evolution of power supply in iron and steel plants has been to electrify every machine, up to and including the main rolls, and to concentrate the power-generating apparatus in a central power house containing steam turbines in regions of cheap fuel and gas engines (with an auxiliary steam turbine for overloads) in regions of dear fuel. Into this evolution stepped the uniflow engine, which now promises or threatens (depending upon the view-point) to change the march of events. In the steel works power plant the uniflow engine will have to compete with the gas engine and with the steam turbine. The gas engine uses 7,500 B.T.U. to 9,500 B.T.U. per indicated horse-power-hour, whereas the uniflow engine, running condensing, uses from 11,000 B.T.U. to 13,500 B.T.U. in the steam and more in the fuel gas, depending upon the boiler efficiency. There is, in consequence, little hope of replacing the gas engine by the uniflow engine.

In comparing the engine and the turbine the variation of



CHARACTERISTIC WATER-RATE CURVES.
Fig. 1.—Water-rate of Compound Engine. Fig. 2.—Flat Water-rate Curve obtained from Uniflow Engine. Fig. 3.—Uniflow Engine Operated Non-condensing. Fig. 4.—Test Results from Uniflow Engine.

steam pressure and of back pressure make it advisable to leave the B.T.U. basis and to introduce Rankine-cycle efficiency, which means the ratio of the work actually produced from a unit weight of steam to the work that could be produced by the same weight of steam passing through the Rankine cycle. From a great number of published tests made on the best turbines, the author has formed the following averages for condensing operation :—

Size of turbine, kw.	500	1,000	2,000	5,000	10,000
Rankine-cycle efficiency :					
Referred to brake h.p.	0·62	0·66	0·71	0·77	0·82

For non-condensing operation the values are much lower.

Data furnished by the Stumpf Unaflow Engine Company, tests made by the author and data from the Ames Iron Works and the C. & G. Cooper Company indicate the following efficiencies from 3lbs. per square inch back pressure above atmosphere down to about 23in. of vacuum.

Size of engine, kw.	300	600
Efficiency :		
Saturated steam.....	71	74
100 deg. superheat.....	75	77
200 deg. superheat.....	78	79
For high vacuum (about 27½in.) :		
Saturated.....	58	62
100 deg. superheat.....	62	65
200 deg. superheat.....	66	68

The values may vary somewhat to one side or the other, but the general tendency is apparent. For non-condensing operation for 100° superheat, for moderate vacuum, and for sizes up to 1,000 kw. the uniflow engine is more economical than the turbine. It will, therefore find a place in comparatively small power plants and in such locations where 28in. of vacuum or better is not attainable. It will also be preferred for generating direct current, because turbines for the generation of direct current when directly connected are too slow for best economy. If they are to operate at economical speed, gears must be introduced. Evidently the uniflow engine will have a limited field in the steel works power plant.

For the driving of rolling mills the uniflow engine was compared with electric drive and with the older type of duo-flow engine. In comparison with electric drive the steam engine does away with the electric generator, the switchboard, the transmission line, and the motor, but it takes undesirable piping into the mill. The elimination of the electrical part means that a comparison must be made of the Rankine-cycle efficiency of the engine to the Rankine-cycle efficiency of the turbine, including generator, transmission line, and motor. Allowing the high efficiencies of 92 per cent. for the generator, 98 per cent. for the transmission line, and 92 per cent. for the motor, it is necessary to multiply the turbine efficiencies by 0·83 for comparison with the direct-connected engine. This procedure furnishes :—

* Abstract of paper read before the American Association of Iron and Steel Electrical Engineers, September, 1916.

Size of turbine, kw.	500	1,000	2,000	5,000	10,000
Rankine-cycle efficiency:					
Referred to motor shaft ...	50	54	59	64	68
Referred to mill shaft.....	47	50	55	60	64

The lower row of figures was obtained by multiplying the upper row by $0{\cdot}965 \times 0{\cdot}965$, this figure taking care of the efficiency of two speed reductions from the motor to the mill. A study of the resulting values shows that the uniflow engine is ahead of the electric drive, unless the steel plant is so large and the load such that turbo units of over 8,000 kw. capacity can be installed.

The economy of the uniflow engine compared to that of the steam-turbine electric drive, taken by itself, is not enough to explain why the uniflow engine should fare differently from the compound engine. The Rankine-cycle efficiency of a good compound engine is practically the same as that of the uniflow engine, but there is one vital difference: To obtain that high efficiency, the compound engine must have a small high-pressure cylinder (which cuts down condensation area), but the small size of the latter means a small overload capacity and quick departure from best efficiency for comparatively small changes of load. Fig. 1 illustrates the water-rate load-curve for a well-known compound engine. Comparison of this curve with the typical water-rate curve of a 20in. by 22in. uniflow engine, Fig. 2, shows the latter curve to be much flatter. The uniflow engine operated at a pressure of 143lbs. to 148lbs., a superheat of 65° to 75°, a vacuum of 25in. to 26in., and a speed of 200 revs. per minute.

Mill loads are notoriously variable, because small variations in draught, temperature of steel, velocity of rolling, &c., cause disproportionately great changes in resistance. It is not possible to exactly foretell what the load will be, and it is, therefore, of the utmost importance to secure a drive which permits overloading or underloading without serious change of economy.

The old type simple duoflow engine, the old reliable stand-by of the rolling mill for over 50 years, cannot be considered here. It is so wasteful that its low price is more than offset by increased cost of boiler-house equipment, not to mention the continuous cost of fuel and water. It retained its place in the mill a long time by reason of its simplicity; it was replaced here and there by the compound engine on account of its wastefulness. The uniflow engine combines the simplicity and overload capacity of the simple engine with the economy of the compound; it has the added advantages that its overload capacity is even greater than that of the simple engine and that its economy is sustained over a greater range of load. Finally, it has few moving parts and takes up much less floor space than the compound engine.

Variation in back pressure naturally affects the operation of the uniflow engine. However, the vacuum may (with 4 per cent. clearance) vary from 19in. to 27in. of mercury without unduly high compression or pounding (due to lack of compression)* If the vacuum fails altogether, clearance is automatically added to keep the compression down.

From personal experience the author knows that a uniflow engine with direct-current generator cost less than a geared steam turbine with generator. From this it may be concluded that an engine without generator, direct-connected to the mill, will cost less than a turbine plus generator, plus switchboard, plus motor, plus gear drive.

The secret of the economy of the uniflow engine lies principally in reduction of internal cylinder condensation. In the duoflow single-expansion engine, cylinder condensation is so great that a very great free expansion loss must be allowed for best economy (or rather for minimum wastefulness). In the compound and triple-expansion engine cylinder condensation is reduced so that the free expansion loss can also be reduced, but mechanical losses due to the passing of the steam through so many valves become great. In the duoflow engine the cylinder head, cylinder barrel and piston head are alternately heated and cooled by live and exhaust steam sweeping over them and wiping heat "on and off." In the uniflow engine only the piston head has heat wiped off during the extremely short period of exhaust, the steam near the place of entrance of live steam being at rest like the fixed end of an expanding coiled spring during exhaust, and like that of a compression spring during compression. Besides, the cylinder head and part of the barrel are steam-jacketed, and steam-jacketed surfaces are cooled very little by stagnant steam. It may be remarked again that the mere provision of a central exhaust does not bring about a successful uniflow engine; the steam jacketing of the heads and of part of the barrel must go with it, to produce the thermodynamic superiority over the duoflow engine.

In the duoflow engine, long compression means increased steam consumption, principally because the steam temperature exceeds the cylinder (or piston) wall temperature a longer time than it would with shorter compression. In the Stumpf Unaflow engine the steam that is being compressed is in contact with progressively hotter surfaces, with the exception of that of the piston, and the steam temperature never rises much above the wall temperature.

The second reason for the economy of the uniflow engine lies in the enforced or compulsory tightness. Steam cannot leak from the live-steam space to the exhaust. If the inlet valves are leaky to any extent, the compression rises so quickly that the inlet valves clatter and give notice to the engineer that some thing is wrong.

The development of the uniflow engine in the United States has been slow. It began in a small way in 1912. The C. and G. Cooper Company, of Mount Vernon, Ohio, the Nordberg Manufacturing Company, of Milwaukee, Wis., and the Mesta Machine Company, of Pittsburg, Penn., began almost simultaneously to build experimental engines. All three firms moved cautiously and equipped their engines with the "old reliable" Corliss gear; all three found out that the Corliss releasing gear, in its usual form, is not ideal for the uniflow engine, because the cut-off is so short, because modern plants carry high pressure with superheat and because the pressure drops so fast after cut-off that the valve becomes unbalanced too quickly for the ordinary design and size of vacuum pot. In consequence, the Mesta Machine Company, and the Nordberg Company, switched over to poppet-valve gears, while the Cooper Company adapted its Corliss gear and vacuum pot to the new conditions. The Mesta Machine Company made its poppet-valve gear non-releasing, while the Nordberg Company adopted a releasing gear.

The smaller sizes of uniflow engines have been developed by the Ames Iron Works, of Oswego, N.Y., and by the Skinner Engine Company, of Erie, Penn. The Ames Iron Works, from the very beginning, adopted poppet-valve steam distribution, with shaft governor drive. This design is well adapted for small engines up to 400 h.p. or 500 h.p., and is very successful. For larger sizes and high steam temperature it is not so well suited, because the difference in expansion between the valve rod and the cylinder becomes too great and disturbs steam distribution. For poppet-valve engines above 500 h.p. the layshaft drive is preferable.

In the sizes built by the Ames Iron Works, a self-supporting piston guided at the crank end only is perfectly satisfactory. In larger sizes this same design leads to a great deal of trouble. On account of difference in expansion the piston must be a loose fit in the cylinder. The guiding of the piston by the crosshead is imperfect. The piston, therefore, wobbles around in the cylinder, riding now on one spot, then on another, never wearing itself in, but rapidly wearing itself out. In large engines of German design a tail-rod guide has been provided, not so much for the purpose of carrying the piston, but mainly for the purpose of guiding it so that it will always touch the cylinder in a large surface. American engineers have gone one step farther and have made the piston rod strong enough to carry the piston.

The early part of the practical development was thorny. Cracked cylinders, heads, and bedplates caused trouble; valve-gear troubles and regulation troubles had to be overcome, pistons and cylinders wore too rapidly. But the problems have all been solved, and the future promises to be free from any obstacles whatsoever. Whatever troubles were experienced, naturally appeared more forcefully in the larger sizes, with the result that the smaller sizes have made more progress in numbers than the larger sizes. It can safely be said that the uniflow engine to-day is as reliable as the simplest engine of the duoflow type.

Figs. 3 and 4 show the steam consumption of various types and sizes of uniflow engines. The results in Fig. 3 were obtained from a 19in. by 22in. engine operating on saturated steam at 125lbs. pressure and atmospheric exhaust. Its normal rating is 240 i.h.p., and the speed is 200 revs. per minute. Fig. 4 was made up from actual test results obtained from larger engines.

* According to experience of the C. & G. Cooper Company.

HEAVY-OIL ENGINES.*

BY S. B. DAUGHERTY.

(*Concluded from page 352*).

Success in Diesel Engine Operation.—On the showing of economy of the Diesel engine, one might ask why the engines are not in more general use, since the United States is the great producer of oil and power is so universally used. One answer is that those who are in a position to reap the most benefit are not aware of the possibilities. Perhaps they have heard of an oil engine installation that has not come up to expectations. Without investigation, they immediately condemn oil engines in general. Or it may be that even when an engine of a suitable type has been installed, satisfactory operation is not obtained on account of the failure of the men in charge to properly care for the engine.

It is evident that in a machine that requires uniformly high pressure to properly ignite the fuel charge, any appreciable leakage of valves or piston rings results in faulty ignition. This applies to the compressor which furnishes the spraying air as well as to the power cylinder. On the other hand, a little intelligent care will prevent trouble of this kind. I know of no case where the proverb, "a stitch in time saves nine," is more applicable.

Another cause of trouble that is avoidable is overloading. A moment's consideration will make plain the ill-effects of overloading. In any internal-combustion engine the amount of fuel burned is limited by the oxygen in the charge of air at the end of the compression stroke. In the case of a Diesel-type engine the time available for burning the fuel charge at full load will not exceed 35° of crank travel. In the case of an engine running 200 revs. per minute this is equivalent to $\frac{1}{34}$ of a second. During the time the oil must enter the cylinder, come in contact with the necessary oxygen, and be consumed. There must of necessity be some excess oxygen in order to effect complete combustion of the fuel. The effect of overloading is to increase the fuel charge so that the amount is greater than can be burned clean with the air that is available. The result is that combustion continues after expansion has begun, and if the overload is great it may even be that the charge will be still burning when the exhaust valve is opened. The temperature of the exhaust gases is then so far above normal that the valve becomes distorted with the heat, causing leaks which still further aggravate the trouble. If an engine be allowed to run with a leaking valve it is only a question of a few hours until both valve and seat will be cut out by hot gases blowing through at high velocities. The secret of success in operating a Diesel engine is in taking care of just such relatively small items. When you find an owner who condemns this type of engine, you will generally find that he is careless, and allows his engine to get out of order in some small particular, and then complains about unreliability, high cost of repairs, &c.

Field of the Diesel Engine.—The Diesel engine has a fairly well-defined field in which it will have no competitor when its merits are known and appreciated. This is the relatively small plant which, when steam operated, is usually inefficient. In generating electric current for a small town, savings are effected that would justify the installation of the Diesel engine if the cost were two or three times what it actually is. For instance, a 300 h.p. engine is effecting a saving of $1,000.00 per month in fuel. In another case a 60 h.p. is saving $2,500.00 a year. In ice making the cost of fuel per ton of ice with oil at 3 cents per gallon is around 18 to 20 cents per ton of ice produced. This includes driving all the auxiliaries, lighting the plant, &c. For pumping, the combination of an oil engine with a geared power pump makes a pumping unit that has a higher thermal efficiency than the best crank-and-flywheel pumping engine ever built, and this efficiency can be obtained when the oil engine is only 65 h.p., compared with hundeds of horse-power in the steam-driven pump. This means that in parts of the country where oil is used under boilers, oil-engine driven pumps in small units are pumping water cheaper than is done by the largest steam-driven pumps. Of course, where heat units in coal can be purchased cheaper than heat units in oil, this advantage of the higher efficiency of the oil engine is offset, but it is probable that there is no place in the United States where the power requirements for pumping are around 50 h.p. to 60 h.p. that an oil-engine driven pump would not be the most economical, all things considered.

The ability to generate electric power cheaply by means of Diesel engines has led to the installation of engines of this type in the phosphate mining industry in Florida. The load conditions are almost ideal for the realisation of high economy. The plants are operated continuously except for a Sunday shut down. It has been found that multi-stage centrifugal pumps motor driven will deliver water at the high pressure required for hydraulic mining at an expense that compares most favourably with compound condensing pumping engines. The advantage of this combination lies in the ability to shift the pump and motor with but little trouble as the mining progresses, thereby saving the expenses and losses due to extending pipe lines from a permanently located pumping unit.

The pipe-line companies have come to appreciate the merits of the oil engine for driving pumps. A large number of units have been installed, mostly of relatively small sizes, the 100 h.p. De La Vergne engine having been very popular. But now that horizontal Diesel type engines are to be had larger units are being used. The economies effected are such that it is only a question of time when steam engines for this service will be abandoned.

* Paper presented at a meeting of the Chicago section of the American Society of Mechanical Engineers, March 17th, 1916.

APPLIANCES FOR HANDLING MATERIAL AT PORTS.*

BY SIR JOHN PURSER GRIFFITH, M.A.I., M.INST.C.E.

(*Continued from page 349.*)

Coal Handling Appliances on the River Thames.—The enormous importation of coal into the Thames for domestic and manufacturing purposes has naturally resulted in some of the best installations in this country for the discharge of coal being found in the Port of London. Although there is some admirable equipment belonging to the several gas companies, yet I propose confining my reference to the plant used by Messrs. William Cory & Son, Ltd. I am especially indebted to their engineer, Mr. H. Shoosmith, M.Inst.C.E., for information and facilities to inspect the company's plant. This plant represents the experience gained from a very large coal trade, extending over a period of 50 years.

In 1858 Messrs. Cory took the first step in the mechanical discharge of coal. They purchased a hulk, or barge, which had been built for wreck-lifting, and was of considerable beam. On this they erected six hydraulic cranes, made by Messrs. Armstrong, three on each side of the barge. The barge was fitted with a gasworks, hydraulic plant, and capstans, and was so successful that a few years later the firm constructed a duplicate plant. The two barges were called "Atlas No. 1" and "Atlas No. 2." For some 20 years they were the recognised stations for discharging steam colliers on the Thames; and the standard specification for a steam collier to trade to the Thames was that the hatches should be made to fit Cory's derricks. As colliers increased in size, four additional cranes were fitted on these barges, one on each corner, with long jibs, which derricked or luffed, so as to vary the radius. These barges were in use up to the year 1900.

The next development was the introduction of coal grabs, in consequence of labour troubles. In 1889 Messrs. Cory built a derrick pontoon, 550ft. in length. This allowed two ordinary sized colliers to discharge on one side of the pontoon. The pontoon was fitted with luffing cranes and grabs which discharged the coal from the steamers into hoppers on the pontoon. From the hoppers the coal descended into an automatic weighing machine, which discharged the coal into a reservoir or bin, from which it was discharged into river barges on the opposite side of the pontoon from the ship. This pontoon, known as "Atlas No. 3," discharged on an average $1\frac{1}{4}$ million tons of coal per annum, and was continuously at work on the Thames until 1915, when it was requisitioned for use in the port of Rouen. When being towed across the Channel, it encountered a very heavy storm and foundered off Dungeness. On account of the obstruction

* The "James Forrest" Lecture, 1916, delivered before the Institution of Civil Engineers.

in the river, the London Port Authority would not allow another coal pontoon to be moored in the river channel. Subsequent additions to the coal handling plant of Messrs. Cory were made ashore.

About the year 1900 Messrs. Cory reconstructed one of their Erith wharves, and erected on it five electric luffing cranes fitted with Hone grabs. A few years later the Erith pier was rebuilt, and furnished with five transporters, to work double chain grabs. The transporters were designed so that the grabs could be raised or lowered, opened or closed, while the grabs were in transit. These transporters are used for unloading coal from the ship, either into railway trucks on the pier or into barges alongside. The transporters are fitted with automatic weighing machines, which have been brought to great perfection, being accurate and reliable. The disadvantage of this form of transporter is that the grab cannot be rapidly lowered into any part of the hatchway, and in their more recent installations Messrs. Cory have reverted to the luffing crane. These cranes, coupled with similar weighing machines to those in use at Erith on the transporters, have worked more satisfactorily. The size of the steam collier has steadily increased, and in rebuilding the coaling jetty at Galleons, Albert Dock, it was decided to be prepared for vessels up to 8,000 tons. The cranes for this depôt have been made with a maximum radius of 83ft., so as to clear such a vessel and load into barges overside. The cranes are fitted with double chain grabs, and are provided with automatic weighing machines.

At Dagenham Dock, Messrs. Samuel Williams & Sons have an admirable coal-discharging plant of the straight line transporter type, but smaller than those in use at Erith. The cantilever extending over the ship can be run in at will and housed so that there is no difficulty in bringing a vessel alongside.

Ore and Mineral Handling Machinery.—The success of the steel industry in the United States of America is principally due to the scientific treatment and economical handling of the iron ore and the coal. The problem of bringing together the coal and iron ore is often one of great magnitude. Distances of over 1,000 miles separate the iron mines around Lake Superior and the coal deposits of Pennsylvania. Yet this transport has been so successfully and economically done that the great steel works of Pittsburg have developed as a consequence. Some of the most striking developments of appliances for handling minerals and ore have been associated with this great industry. From the mines the ore is brought by rail to the lake port, where special docks have been constructed at which the lake steamers are loaded. At these docks huge bins have been built, over which the trains of wagons run and drop their loads. From these bins the ore can be discharged by shoots into every hatch simultaneously. The great charm of this arrangement is that the bin storage ensures continuous loading, and vessels are not delayed awaiting the delivery of the ore by the wagons.

Ore Transport Steamers on the American Lakes.—Specially-designed steamers are features of this trade. The following description of one of the more recent steamers will serve to describe the class as a whole, although dimensions vary. The vessel I have in mind is 560ft. in length over all, 56ft. beam, and 32ft. in depth. The cargo hold is free from stanchions and cross-bracing or bulkheads. The sides and ends of the hold slope in the form of a hopper. The hold in the instance referred to is 409ft. long, 43ft. wide at the top, and 24ft. wide at the bottom. Arched transoms span the hold about 12ft. apart. These transoms support the upper works and hatch covers. The vessel carries 11,000 tons of ore, and is fitted with water ballast tanks in the double bottom and sides. The decks are of such a form and size that several vessels can be loaded at the same time. At Duluth in one dock 64,000 tons of ore have been loaded into 14 vessels in 24 hours, or an average load per vessel of 4,571 tons.

The unloading of vessels is what limits the speed, and a study of the various methods adopted is of great interest. I should like to refer briefly to the Hulett system, which, as far as I have been able to discover, is one of the most effective methods in use on the Great Lakes. The Hulett unloaders are designed to work either by steam or electricity. The machines consist of a movable crane or gantry, travelling along tracks parallel to the waterway, and spanning any desired number of railway tracks. This gantry carries two girders at right angles to the face of the dock. Along these girders a trolley or carriage, carrying a walking frame, travels backwards and forwards. At the outer end of this beam there is a vertical leg, at the lower end of which is the scoop or grab, having a capacity of from 3 to 17 tons. This leg is hung on trunnions, and can be rotated in either direction. By means of hoisting mechanism the walking beam is made to oscillate up and down, carrying the leg and grab down into the vessel's hold, and up again on to the quay. These machines are primarily designed for handling ore from the ship to the railroad car direct, but when it is necessary to store the ore for a length of time in stock piles, the crane or gantry is provided with a cantilever extension, running back at a sufficient elevation, to clear the piles of ore.

In working the unloader, the trolley or carriage runs out on the girders, the outer or water end of the walking beam is brought down till the bucket-carrying leg enters the hatch, and the grab rests on the ore in the hold. The grab is then closed, the leg raised, and the trolley brought back into a position from which the ore can be dumped through a shoot into the railway cars beneath, or, after running up the cantilever extension, on to the stock pile. The operator controlling all the motions of the machine, except moving along the dock, stands in the leg immediately over the grab, going down through the hatch with it, and watching the operations of the grab very closely. By means of the rotating trunnion, the operator is able to make the grab reach all the ore in the vessel. The wide open spread of these grabs is from 18ft. to 20ft. These machines have removed, without trimming, 95 per cent. of the cargo of a modern vessel, with a minimum rate of unloading of 200 tons per hour, and a maximum of 680 tons.

The Brown Hoisting Machinery Company, of Cleveland, Ohio, have constructed some excellent coal and ore handling plant, and have been kind enough to obtain for me some photographs of the most striking examples. Amongst these is the coal handling installation of the Pittsburg Coal Dock Company at Duluth, Minn. It is said to be the largest in the world, capable of taking coal from steamers to a 1,000,000 tons storage yard at the rate of 1,500 tons per hour. A special automatic screening apparatus is provided for separating the coal into the various marketable grades. Another interesting plant is at work at Fairport, Ohio, and consists of six fast unloading electric trolley grabs, delivering ore from the ship either to rail or store. Five-ton grabs are used, and 10,000 tons of ore have been discharged in 9 hours.

Grain-handling Appliances.—England lagged behind in the adoption of grain-handling appliances, and we are still familiar with old methods of filling the grain into sacks in the holds of vessels, hoisting the sacks on deck by hand or steam winches for weighing and adjustment, transferring the sacks on men's backs to carts or railway wagons, whence they are transferred to the granaries. The granary in these islands, until a comparatively recent date, consisted of a warehouse with floors on which the grain was stored to variable depths by manual labour. The first advance was the introduction of elevators for raising the grain to the several floors, and belts and shoots to distribute the grain over the floors. Gangs of labourers were, however, still employed for turning it over for cooling.

In America, at a very early date, the handling of grain became a pressing problem. The economical transit of grain from the freshly broken-up prairies of the West to the European markets was a matter of vital importance to the Western States. Dearth of labour gave the impetus to the invention and introduction of mechanical appliances, and the erection of silos, or bin-stores, was one of the earliest and most important steps. The combination of elevators and silos solved the problem of storage. The force of gravity was utilised in every possible way. The mechanical elevator raised the grain in the most economical manner to any required height, from whence it could be distributed by gravity from the store to the wagons, ships, or barges. Even

after great progress had been made in the loading ports of the United States, the handling of grain at the discharging ports of Europe, and specially at those of the British Isles, was antiquated and costly.

Considerable progress has, however, been made of recent years in the discharge and handling of grain in our European ports by the introduction of fixed or portable elevators on land, or by floating elevators in the docks and harbours. The elevator leg with its chain of buckets is lowered into the hold of the vessel where grain is carried in bulk. These elevators are worked by steam or electricity and discharge the grain ashore, or into barges or vessels lying alongside. The pneumatic discharge of grain, which was introduced by Mr. Duckman, of the Millwall Docks, about the year 1890, has of recent years made considerable progress, especially abroad. Suction pipes are lowered into the ship's holds, and the grain extracted and delivered into adjoining stores, or overside into barges or ships. Although a British invention, it has been chiefly developed in the principal continental ports. A large number of floating pneumatic elevators, constructed by Messrs. Luther, of Brunswick, were, before the war, at work in the port of Rotterdam, where immense quantities of imported grain were transhipped from ocean-going vessels to the great river barges which navigate the Rhine.

Pneumatic elevators are specially useful for the discharge of grain carried in parcels in the various holds of the modern ocean trader. It would be impossible to pass the ordinary bucket-elevator into many of these holds, but the pneumatic suction pipe can be led through the smallest hatchway, passed round angles, and the inlet nozzle led into the most remote corners of the holds, dispensing entirely with manual labour otherwise necessary to trim the grain to the elevator. Pneumatic discharge requires greater engine power than the ordinary bucket-elevator and distributing-belts to handle the grain ashore. There can be no doubt but that the pneumatic discharge is advantageous to the grain, for it separates the dust from the grain, and removes a fruitful source of heating. And yet, curiously enough, this separation of the dust from the grain has actually proved a deterrent to the use of pneumatic plant, the reason being that the removal of the dust meant a material loss of weight, although the quality of the grain was improved. In many instances arrangements have been made to return the dust to the grain before it is passed to the weighing machines.

Oil-handling Plant.—The story of progress in the handling and transport of petroleum reads like a romance. The important part it and its by-products play in our every-day life has been brought into prominence by the restrictions in its use forced upon the nation by the world-wide war now in progress. We have learned how dependent we are on its supply.

Amongst the first important discoveries of petroleum we may refer especially to those in Pennsylvania, when William Drake "struck oil" in 1859, less than 60 years ago. In those early days of the industry the oil wells and the refineries were close together. This was principally due to the heavy cost of carriage to the markets, the refined oil being at that time the principal marketable product. The oil was transported in wooden barrels, carried in barges on the waterways, or in horse wagons by road, and at a later date by rail. As the industry extended, and shipments to Europe increased, the discovery was made that transport through pipes to large refineries near the coast was feasible and economical. The battle of vested interests was fiercely fought over this revolutionary change, but the pipe-line won the day over the transport wagon. Thousands of miles of trunk pipes ranging from 4in. to 8in. diam. exist for the transport of petroleum from the wells to the refineries, while tens of thousands of miles of smaller feeder pipes have been laid to collect the oil from its various sources, and lead it to the delivery or trunk mains.

The introduction of large and scientifically equipped refineries was followed by the discovery of the value of the distillations and by-products of the crude oil. The crude oil was separated into three principal groups: inflammable oils, burning oils, and lubricating oils. With advances in the refining process, the cost of production greatly decreased, and the export trade to Europe advanced by leaps and bounds. Although the transport of oil through pipes on land had made such progress, yet its transport across the Atlantic continued in barrels for many years. This old system of sending oil in barrels in sailing vessels was in full swing in the eighties, and in the Port of Dublin until 1899, when the Anglo-American Oil Company opened their tank storage depôt. The first tank steamer entered the Port of Dublin in February of that year. The effect was startling. Instead of a sailing vessel with from 1,000 to 2,000 tons of oil in barrels occupying the harbour quays for weeks, the tank steamer with from 5,000 to 10,000 tons of oil was discharged, and the oil pumped ashore and stored in the depôt tanks, within from 24 to 48 hours from the arrival of the tank steamer. Thus, to the great advantage of the port, through shorter occupation of its valuable berthage and freedom of the quays from the obstruction caused by barrels, this application of modern methods of handling petroleum has reduced the cost of oil to the consumer, cheapened freights, and added to the available usefulness of the harbour space.

The shortage of tonnage of tank steamers caused by the war has this year forced the Anglo-American Oil Company to import a certain amount of oil in barrels by sailing ships, and we have been forcibly reminded in Dublin of what this means. The Norwegian sailing ship Nordfarer brought 18,500 barrels of petroleum in August of this year, approximately equal to 3,000 tons of oil. This vessel, even with the aid of electric cranes, took 10 working days to discharge, whereas if that amount of oil had been imported by tank steamer, it would have been discharged in one day—a saving to the port of 9 working days.

Timber Handling.—The handling of timber, both at the loading and discharging ports, still involves much manual labour. Until quite a recent date balk timber was brought in rafts for shipment, and hauled into the holds of sailing vessels through port-holes formed in the ship's bows. On arriving at their destination, the balks were discharged into the water through the same port-holes, and formed into rafts either for storage or transit. The timber was hauled into or out of the ship's port-holes by winches and tackle. With the advent of the steamship into this trade, the balk timber is generally loaded and discharged through the deck hatches by the ship's steam winches and derricks. In the Port of Dublin the timber is now frequently discharged by the portal electric cranes on the quays with satisfactory results as regards time, and great facilities for stacking and handling the timber on the quays. Planks, deals, and boards were formerly exclusively discharged by manual labour, but have of late been discharged, landed, and stacked by the electric cranes. Conveyors have been introduced in some places where the timber storage ground is within reasonable distance from the quay, and elevators of a special form have also been adopted in a few places for stacking planks.

Appliances for Handling Heavy Machinery, &c., in Ports.—In a large port it is essential to have appliances to deal with heavy lifts, such as railway rolling stock, engines, boilers, and machinery of all kinds. The example to which I would draw your attention is the 100-ton electric crane in the Port of Dublin. Before its erection, in the year 1905, it was no uncommon occurrence for heavy loads to be sent round to Belfast instead of being landed in Dublin. The crane is of the hammer type, all the weight of the crane and load being carried by the crane post to a bearing on the ground level, the over-turning moment being taken up by a four-leg trestle frame, with horizontal rollers and roller path at the top of the frame. The crane is capable of lifting loads up to 100 tons at a radius of 75ft. An auxiliary lift is provided for loads under 20 tons, working to a maximum radius of 80ft. The test load of the crane was 150 tons. Loads between 50 and 100 tons can be raised at the rate of 5ft. per minute, and below 50 tons at the rate of 10ft. per minute, with the main hoist. Loads below 20 tons can be raised at the rate of 20ft. per minute by the auxiliary hoist, and the crane can make a complete revolution with any weight in eight minutes. The contractors for the steel work were the United Machine Manufacturers, of Augsburg and Nuremberg; Messrs. Siemens Brothers were sub-contractors for the electrical equipment; and all foundation work and masonry

were carried out by the engineer's department of the port. The methods adopted for the erection of the crane, including the steel staging, were striking exhibitions of the best German practice, and for efficiency and thoroughness were full of interest to the engineer, and worthy of imitation.

Appliances for Handling General Merchandise. — From amongst the numberless appliances for handling general merchandise, I have selected some examples of elevator-conveyors and runways which are in use in several of our British ports for dealing with frozen meat, cheese, and tea. I am indebted to Messrs. Rownson, Drew, & Clydesdale, of Upper Thames Street, for several photographs showing this plant at work in the Port of London. These photographs show Donald's patent elevator-conveyor being taken to a ship, erected on a ship, and removing frozen meat from a White Star steamer to carts and railway wagons. There are also views of similar elevator-conveyors dealing with cheese and tea.

Reference has been chiefly made to appliances for loading and unloading vessels; but, in addition to these, there is the necessity of being able to handle the cargo when it is on land either before loading or after discharge. Unless the quays and sheds are cleared rapidly, it is obvious that the discharge and loading of vessels will be delayed for want of quay space to deposit and sort the goods. If a port is not sufficiently provided with well-designed sheds and ample quay space for the reception of cargoes and appliances for handling and sorting merchandise of all descriptions, loss and extra expense will be incurred. Facilities for the rapid removal of goods from the port are also of the greatest importance, while easy connections with the railways and the inland navigations of the country are essential in the interests of the internal trade of the country. In this respect some of our older ports controlled by port trusts labour under great disadvantages when competing with more modern ports, and specially with those controlled by railway companies. The defective railway connections of the older ports often necessitate costly cartage between the ships and the railways.

The railway-owned port has the advantage of a co-ordinated control of its railway and shipping traffic arrangements. A similar remark applies to traffic arrangements where railway companies own fleets of steamers trading to a port, and are able to connect their railway system with the berths occupied by these steamers. In this connection I should wish specially to refer to the arrangements of the Lancashire and Yorkshire Railway Company at the Port of Goole. Through the kindness of Mr. J. A. F. Aspinall, the general manager, his goods traffic manager, Mr. Marriott, and the chief engineer, Mr. Rattray, I was able to visit the Port of Goole and inspect the arrangements for handling the company's continental traffic at that port. A single-story shed, with large floor area, has been erected at the steamboat berths, into which the railway wagons run. There is ample floor area for depositing goods, and this is commanded by overhead cranes which traverse the shed from the quay to the rails. An ingenious combination of jib cranes and overhead cranes allows of the cargo being taken out of the ship's holds, and landed either in the sheds for sorting purposes, or into railway wagons standing at some considerable distance away.

One of the best examples of handling goods traffic of a general character which I have seen is at the Lancashire and Yorkshire Railway, Oldham Road Goods Station, Manchester, where a very complete system of overhead electric cranes deals with all classes of traffic, and electric motor trucks are used on the platforms to supplement the cranes for taking goods from one portion of the shed to another. The arrangements for handling, sorting, and delivering the goods are about the most perfect which I have met with, and are worthy of study by those interested in this most important economic problem. The handling of wool and cotton in the manufacturing areas of Yorkshire and Lancashire has taxed the ingenuity of railway engineers and managers. The enormous volume and bulkiness of the packs of wool and bales of cotton arriving at such centres as Bradford, Manchester, and Oldham make the handling and storing of these materials a gigantic problem. The principle now generally accepted as the best is to pile the bales to a great height, irrespective of their marks, in sheds commanded by overhead cranes. Some of the finest examples of this kind of storage are to be found at Werneth, where the Lancashire and Yorkshire Railway have a large shed for the storage of cotton, and at the cotton safes of Trafford Park, which have been evolved by the ingenuity and enterprise of Mr. Marshall Stevens, the chairman of the Trafford Park Estate, Ltd. This system has also been adopted at New Orleans, whence so much cotton is shipped. The same principle is adopted in the more modern wool warehouses at Bradford belonging to the Lancashire and Yorkshire Railway.

The Influence on Labour of Appliances for Handling Raw Materials and Merchandise.—There is an aspect of the problem under discussion which appears to me of supreme importance and interest, namely, the effect on labour of appliances for handling raw materials and merchandise in our ports. "Labour-saving appliances" is a familiar expression. Is it a strictly accurate term? The working man understands it as meaning arrangements for doing without him. He views with suspicion all machinery which tends to expedite output. His idea is that its introduction means so many men displaced, and so many men thrown out of work, the earning power reduced, and increased poverty the result. Have these fears been justified by past experience? I think not. Instead of speaking of "labour-saving appliances," can we not gradually substitute the term "labour-aiding appliances"?

Allow me to quote a sentence of Mr. Harold Cox in his lecture to us on "Industrial Improvement" last March, with which I am in complete sympathy. His words were: "Unfortunately, we still find that workmen in many places look upon improvements in machinery with very much the same suspicion as in the beginning of the 19th century, when they used to break the power-looms. It is very curious, for when you come to think of it, the first instinct of man, however uncivilised he may be, is to make a tool to help in his work. Indeed, man might almost be defined as a tool-using animal. I venture to lay down this proposition that, so far as material comfort is concerned, the progress of mankind is dependent upon the progress of machinery."

(*To be continued.*)

DETERMINATION OF NOMINAL HORSE-POWER.

THE Marine Department of the Board of Trade have just issued the following circular of Instructions to Surveyors:—

Under Section 92 of the Merchant Shipping Act, 1894, foreign-going steamships of 100 n.h.p. or upwards are required to be provided with at least two certificated engineers. The following alteration is made in the formula to be used by surveyors for determining the nominal horse-power where there is doubt whether the nominal horse-power is over or under 100. The present formula is:—

$$\text{N.H.P.} = \frac{S}{30}$$

where S is the sum of the squares of the diameters in inches of all the cylinders. The formula to be used in such cases in future is:—

$$\text{N.H.P.} = \frac{(3H + D^2\sqrt[3]{S})\sqrt[3]{P}}{700}$$

where H = heating surface of main boilers in square feet, measured down to the level of the fire bars, but excluding the front tube plate.

D^2 = square of diameter at low pressure cylinder, or sum of squares of diameters of cylinders in non-compound engines, measured in inches.

S = length of stroke of engine in inches

P = pressure of main boilers in pounds per square inch.

The Manufacture of Lifting and Conveying Machinery.—The Minister of Munitions in the exercise of his statutory powers has required all persons, firms, and companies engaged in the manufacture of cranes, aerial ropeways, capstans, conveyors, grabs, elevators, hoists, lifts, runways, shear legs, transporters, travellers or winches, whether operated by steam, electric, hydraulic, pneumatic, or hand power, not to carry out without a permit issued under his authority in any factory, workshop, or other premises, any work consisting of the manufacture, assembling, or erection of any of the above-mentioned articles except under: (*a*) Orders received from or in connection with work for the Admiralty or War Office; (*b*) orders of a value not exceeding £50 required for war work; (*c*) orders which have already been sanctioned by the Ministry of Munitions as Class "A" work.

CORRESPONDENCE.

After-the-War Trade.

To the Editor of "The Mechanical Engineer."

Sir,—Germany's intention to obtain an initial advantage in the fight for the world's trade is plainly seen in the social and economic reconstruction that has been proceeding throughout the Fatherland side by side with the country's gigantic efforts on all the war fronts. In nothing is this idea of Germany more plainly seen than in the latest scheme announced, by which the great armouring firm of Krupp, with its scores of thousands of mechanics, is to be linked up with the North German Lloyd steamship lines. The Essen firm has now purchased an interest in the steamship company, and one of its directors is to have a seat on the board.

When war broke out official Germany had so organised its machine shops that only the pressure of a button was required to switch all the works on to munition making. All that is happening now shows that at the psychological moment the same procedure will be adopted, with this difference: German machinery will make wares for the world's marts instead of munitions for the Fatherland.

The adroit move of Krupp and the steamship company is not a mere private commercial transaction. It has a much wider significance of which we, in this country, should take due note. While Teuton submarines have been busily engaged sending to the bottom as many British ships as possible, existing German craft have been safely interned in home or neutral ports. Meanwhile, German shipbuilders have been steadily building new vessels for the Mercantile Marine, some of them of 20,000 tonnage. It is Germany's ambition to emerge from the war, even if beaten, as the first shipping power in the world, and the new link forged between Essen works and Bremen ships is another move in a well-matured plan to realise this aim.

The question naturally arises in one's mind whether we, as a nation, shall once more be caught napping. How far positive progress has been made by any of the Government Committees appointed to consider questions of after-the-war trade it is impossible to say, since not one of the Committees has issued a report. Months ago there was noticeable activity in certain industries, chiefly in the formation of trade associations, but this seems to have died down.

Wise men judge the future by the past, and, adopting this formula, we shall probably find that British trades and industries will progress and flourish just in proportion as they concentrate their energies now upon perfecting their organisations and co-operating in a commercial campaign conducted in every corner of the world. In a word, our industries will rise or fall according to the wisdom and the extent of the efforts of their organisers.

So far as the motor engineering industry is concerned, we feel that it will require a far more powerful effort than has yet been put forth if it is to cut a creditable figure in the impending trade war, and anything that the Government can do to strengthen the position will be heartily welcomed.

—Yours truly, BARIMAR, LTD.

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1915.

Gravity feed devices for boiler feed water. Fowler. 4055.
Manufacture of cold drawn thin walled tubes. Von Forster. 11770.
Apparatus for actuating signals on trains and for stopping trains independently of drivers. Biddle. 11941.
Spanners and wrenches. King. 13266.
Reversing mechanism for internal combustion engines. Willadsen. 14412.
Bearings. Bunting. 14435.
Pistons. Sanderson & Wood. 14527.
Carburetters for internal-combustion engines. Torrens. 14610.
Burners for producer-gas. Hall. 14624.
Steam superheaters for locomotive boilers. Robinson. 14657.
Dynamometers. Heenan & Froude, Ltd., Heenan, and Walker. 14885.
Rock drills and coal-cutting machines. Mauss. 14919.
Means for controlling the supply of liquid fuel to oil engines. Petter. 14924.
Valve-operating means. Svenska Aktiebolaget Gasaccumulator. 14967.
Means for regulating and controlling temperature. Hall. 14996.
Lathes. Cole. 15973.
Ships for carrying liquid cargoes in bulk. Laing & Ashby. 16016.
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Condensing apparatus. Hick, Hargreaves, & Co., and Gunn. 16918.
Forced draught systems for marine boilers. Roberts. 17483.
Control mechanism of boring and turning mills. Webster and Bennett, Ltd., and Thompson. 17939.

1916.

Acetylene burner. Fairbrother, H. 370.
Spanners. O'Gorman, M., and Stallwood, G. 1048.
Air pump. Jarvis, E. H., and Bradbury, H. W. 1091.
Toolholders. Judge, T. A., and Harvey, H. 1776.
Furnaces. Thompson, C. H. 4167.
Adjustable hangers for power transmitters. Fairweather, W. 5546.
Pulleys for belt gearing. Morgan, J. H. 9340.
Valve mechanism. Miller, H. P. E., and Tetlow, E. 10389.
Devices for locking together bolts and nuts. James, R. E. R., and James, C. W. 11239.

ELECTRICAL, 1915.

Dynamos. La Cour. 103.
Protective devices for electric distribution systems. British Thomson-Houston Company. 14482.
Time-limit circuit breakers. Akt.-Ges. Brown, Boveri, et Cie. 14498.
Interrupters for inductive electric circuits. Harry W. Cox & Co., and Ten Bruggenkate. 14503.
Galvanometers. Sullivan. 14553.
Dynamos. Heys. 14633 and 14643.
Wireless telegraphy. Long. 14729.
Magneto-electric machines. British Thomson-Houston Company, and Ralph. 14851.
Protective devices for electric circuits. British Thomson-Houston Company. 15633.
Dynamos. Electromotors, Ltd., Longbottom, and Greenhalgh. 16640.

1916.

Fluid-pressure-controlled collectors for electricity. Vacuum Brake Company, Dover, H. J., and Walker, W. P. 1116.
Electrolytic refining or extracting process. United States Metals Refining Company. 5750.

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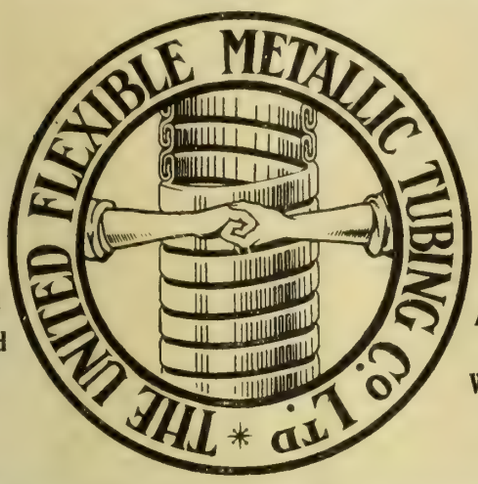

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Gas-fired Boilers and By-products.

THE problem of fuel economy, as we pointed out in the editorial in our last issue, presents many aspects, and cannot be resolved into a cut-and-dried solution for every case. In connection with steam generation the boiler plant must be considered, and in this questions of space and capital expenditure enter as well as fuel cost. Low-grade fuel and forced draught may be used, and yet their advantages be nullified by extra space and outlay. Numerous attempts in the past have been made to overcome these difficulties by firing with gas generated in independent producers. The experiments, however, did not prove satisfactory, owing mainly to the fact that gas firing calls for greater heating surface. Great advances have been made since then as regards the utilisation of fuel in producers as a result of the developments in the by-products industry on the lines first indicated by Dr. Mond, and experience in this direction has suggested economical applications of gas firing and recovery processes to boiler plants which a few years ago did not seem possible, but which now foreshadow important developments. An interesting communication bearing on these has been made by Mr. Geo. Wilkinson, borough electrical engineer of Harrogate, to our contemporary "The Electrical Review," which is worth noting. After explaining that the Harrogate works is situated on a valuable building site which is considerably depreciated by the fact that the chimney is an eye-sore, he explains that he has designed a boiler which will enable this eye-sore to be removed. The scheme includes the distillation of the coal so as to obtain tar and ammoniacal liquor as by-products, and the gravitation of the resulting coke into the boiler furnace in an incandescent state, where it is consumed without smoke and without loss of heat, while the gas distilled at low temperature is, after

being denuded of the by-products, forced into the furnace under pressure along with the necessary air, and its heat utilised by Prof. Bone's system of flameless combustion. The arrangement is ingenious, and although, in the absence of actual working trials, it would be premature to pronounce a final opinion of its merits, it certainly seems very promising. It is easy to understand that it will involve increased capital expenditure, but by-products are so valuable that where they can be secured they amount to a serious rebate on the price of the coal, and may well repay capital outlay. The possibilities presented are at least well worth extensive trials. With efficient recovery plant the quantity of fuel used might conceivably be a minor consideration, and even in itself a valuable asset. Considerable experimental work in this direction has, we believe, been already done, apart from the scheme outlined by Mr. Wilkinson. We are not in a position as yet to give details of this, but it will be evident from what we have outlined that the near future may reveal opportunities for economy in the use of fuel for steam generating purposes and at the same time provide a solution of the smoke problem in towns which will amount to something like a revolution in boiler practice.

Safety Valves on Heating and Domestic Boilers.

A SAD fatality that occurred in Manchester about a fortnight ago, when, owing to the bursting of a boiler used for heating some office premises, a man and his two children were scalded to death, serves to emphasize the importance of such apparatus being under competent inspection. The evidence at the inquest showed that the boiler was not equipped with any safety valve or pressure gauge, and that in the event of its beng disconnected from another one it was hermetically sealed, and if a fire were lighted its explosion was inevitable. This was what actually took place. Owing to some defect which necessitated repair, the valve connecting the boiler to its companion one was shut, and the attendant proceeded to light the fire, with the dire results stated. The risk of working any boiler without a safety valve, even if only used for domestic or heating purposes, has been pointed out by us repeatedly, but it appears difficult to impress the fact on those who use apparatus of this kind. When a sharp frost comes its effect on domestic boilers is usually evidenced by a crop of failures, and as the period is approaching when a spell of intense cold may supervene at any moment a note of warning on the matter may not be out of place. It cannot be too strongly insisted upon that every boiler should have its own independent safety valve directly connected to the boiler without any intervening taps or valves, and placed so close to it that there is no possibility of an ice block existing between the safety valve and the boiler when there is pressure in the latter. To rely upon a safety valve on an adjoining boiler is a standing invitation to trouble and disaster.

SHIPBUILDING IN 1915-16.

THE Annual Report of Lloyd's Register of Shipping for the year 1915-16 states that in few industries has the effect of the war been more widespread and far-reaching than in the domain of shipping. The disappearance from the high seas of the merchant fleets of Germany and Austria-Hungary, and the continued losses of allied and neutral shipping, combined with the enormous demands which the war has made upon the available tonnage, produced a shortage which has stimulated the building of ships in every country free to engage in ship construction. In the United Kingdom merchant shipbuilding is still seriously restricted by the necessity for the production of war vessels of various kinds; and, although there has recently been some acceleration in the rate of progress in the construction of vessels, the output remains far below that of normal times. In neutral countries, and particularly in the United States of America, every effort has been, and is being made, by means of the extension of existing plants and the creation of new establishments to cope with the increasing demand for tonnage. That a large measure of success has attended these efforts is evident from the fact that there is now being built under the inspection of Lloyd's Register of Shipping, with a view to classification, a larger amount of shipping than has ever been recorded in the history of the Society, namely, 620 vessels of 2,282,709 tons.

At the close of the year ended June 30th, 10,032 merchant vessels, registering over 23 million tons gross, held classes assigned by the Committee of Lloyd's Register. These figures, large as they are, show a falling off from the high-water mark of the previous year. During the year under review, the Committee passed the plans of 742 vessels, representing 2,375,590 tons of shipping, to be built under the Society's survey with a view to classification in Lloyd's Register book, as compared with plans of 733 vessels, of 1,715,500 tons, for the previous 12 months. The Committee assigned classes to 362 new vessels, of 790,209 tons, of which 356 were steamers or motor vessels, of a tonnage of 789,688, and six were sailing vessels of 521 tons. Of the total 414,462 tons, or about 52½ per cent., were built for the British Empire (United Kingdom 397,852 tons, Dominions 16,065 tons), and 375,747 tons, or about 47½ per cent., for other countries.

One of the most important of the subjects which have engaged the attention of the Committee during the past year has been the Society's business in the United States. The great development of the shipbuilding industry in America, and the fact that the bulk of the tonnage in course of construction there is being built under the Society's survey, lent force to the wish of many of the clients of Lloyd's Register in that country that some arrangement should be made to bring them into closer association with the Society; and the Secretary was accordingly instructed to visit the United States with a view to consulting with the leading shipping men on the subject. As a result of the negotiations which ensued the Committee recently announced that an American Committee of Lloyd's Register of Shipping had been established in New York, composed of leading underwriters, shipowners, and engineers.

The tonnage classed by the Society during the year includes 32 vessels, of 156,975 tons, built upon the Isherwood system of longitudinal framing. Up to date there have been built, or are in course of construction, upon this system, to the Society's classification, over 470 of these vessels, totalling 2,650,000 tons.

The number of vessels intended to carry oil in bulk which have been classed by the Society during the year under review is 14, of 77,167 tons. The total number of such vessels at present classed in Lloyd's Register Book is 301, of 1,380,235 tons gross. Vessels fitted for burning oil fuel holding classes assigned by the Committee number 269, of 1,259,714 tons. Owing to the increasing demands made for oil in this country, many proposals to supplement the supply by converting ordinary cargo steamers into oil carriers have been dealt with by the Committee. The Society's classification has been assigned to vessels in which the oil is carried in large circular tanks built into the holds, and arrangements have been approved which will admit of fuel oil with a high flash point being carried in the double bottoms of cargo vessels, provided the construction is suitable for the purpose.

Light Brass-work Contracts Available. — The Ministry of Munitions is desirous of extending the output of casting and stamping fuze bodies and sockets, and casting and rolling brass rods for the components. Firms possessing suitable machinery and capable of undertaking such work are requested to communicate with the Central Clearing House for Engineering Resources, Ministry of Munitions, 8-9, Northumberland Street, London, W.C.

Nine vessels have been built to the Society's classification during the past year in which steam turbines have been fitted, all geared. At the present time there are 52 vessels in course of construction, with a view to being classed in the Society's Register Book, in which geared turbines will be fitted.

In the United Kingdom there are two vessels being built to the Society's classification in which the Ljungstrom turbo-electric propelling plant will be fitted, one a single-screw vessel, in which the power will be 1,500 s.h-p., and the second a twin-screw vessel, with a total shaft horse-power of 5,400.

During the year seven vessels classed by the Society have been fitted with Diesel engines. There are now 46 vessels holding the Society's classification which are fitted with engines of this type, and, in addition, there are at present in course of construction under the Society's survey, over 30 sets of these engines. In addition to the foregoing, several vessels have been fitted with oil engines of other than the Diesel type, among which may be mentioned 11 fitted with hot-bulb engines made by the Bolinder Company of Stockholm, and this type of engine is to be fitted in more than 30 vessels which are being built under the Society's inspection.

The Institute of Metals having expressed a wish that a representative of Lloyd's Register should be appointed to serve on the Corrosion Committee of that Institute, the Committee nominated the Society's chief engineer surveyor for the purpose. The Corrosion Committee are conducting experiments with a view to determining the best means to be adopted in order to reduce corrosion in condenser tubes. Similarly, the Society's chief engineer surveyor and chief ship surveyor were nominated as representatives of Lloyd's Register on the Ship-wiring Rules Sub-Committee of the Institution of Electrical Engineers.

The Technical Committee have had under consideration during the year a few proposed modifications in the Society's rules for the construction of ships and machinery, and the recommendations of the Technical Committee on the subject have been adopted by the General Committee.

SAFETY IN USE OF OIL BURNERS.

BY A. C. MC.HUGH.

SERIOUS accidents to engineers and firemen are of frequent occurrence from the practice of improper methods of lighting and handling oil fires, and it is the writer's purpose to call attention to a few general rules which, if followed, will greatly lessen the danger of injury to those using oil fuel.

Oil burners may be broadly divided into two classes—those that use steam for atomisation of the oil and those that do not. As the former are more generally used, the present remarks will be confined to steam atomising burners. These are of two types—the inside mixture type, in which the oil and steam come together inside the burner and are introduced to the furnace through one slot; and the outside mixture type, by which the oil and steam are introduced separately. There is, however, very little difference in the method that should be employed in lighting or handling either type.

In starting a new fire the steam should be turned on and the bypass opened in order that the oil and steam passage may be cleaned out and warmed up. The bypass should then be closed and the steam shut off. Then the damper must be opened. This is one of the most important things to impress upon one's mind. Do not try to start a fire with a damper closed. Next light a torch or bunch of oily waste and place about 10in. to 12in. in front of the burner, turn on a small amount of steam (just enough to carry the oil from the burner tip to the torch) and crack the oil control valve a little. As it generally takes some little time for the oil to fill the burner passage, do not turn on more fuel but wait until the passage is filled, when the fire will light easily.

Until the furnace is thoroughly warmed up, the fire should be closely watched, as it is easily put out, especially if either the steam or oil contains much water. Should the fire go out and the oil still be left to flow, the heat of the furnace will generate volatile gases that will appear at the stack in the form of a greyish-white smoke. Should a torch then be applied, a violent explosion would occur. Cases are on record where these gases have been ignited through the breechings of other boilers. The moment the fire is out, the oil should be shut off and the door opened. After a few minutes the gases will have passed off and the fire may be rekindled. When the furnace is hot, there is not so much danger, as the incandescent furnace will immediately relight the oil if its flow should be interrupted for a moment; but even then no chances should be taken, for it is in this way most men are burned. The fire goes out; the attendant opens the door, and turns on more oil, expecting it to light immediately, which it generally does, to his sorrow. It is always cheaper to rekindle than to take a chance. In regulating a fire the attendant should hold the door open just enough to enable him to watch the flame and be in a position to duck his head in case of a flare back. To increase the fire the oil valve should be operated first, then the steam turned on until the flame is clear. If not enough steam is used, the flame will appear red and smoky; too much steam will cause the fire to look ragged and will have a tendency to extinguish it. In reducing the flame the steam is throttled down first, then the oil is reduced.

Once the fires have been set, they may be regulated over quite a range by increasing or decreasing the pressure applied to the oil supply without opening the fire-door or changing the steam supply. This can be done by manipulating the pump throttle or a bypass valve between the suction and discharge lines.

When extinguishing a fire, the flame should be cut down as low as possible; then by opening the bypass immediately after shutting the oil valve, the oil passage will be blown out without danger, as the flame will not be extinguished until the passage is clear.

Another point of great importance is that of air supply, or draught regulation. The importance of smokeless combustion is impressed upon the minds of nearly everyone. In fact, a smokeless stack is demanded of all oil-burning plants, but the fact is that a large percentage of these same smokeless plants are operating in utter disregard of fuel economy. One of the chief virtues of oil over coal as a fuel is the fact that on account of its volatile nature, it is more readily mixed with air, thus permitting the air supply to be reduced to a minimum. In properly designed furnaces but little more than the theoretical amount need be used, but in a great many plants little or no attention is paid to this, and as a result, the average oil furnace is more wasteful than the average coal furnace, because of the small resistance offered to the passage of air, there being no fuel bed to check its flow. Thus without close regulation large quantities of air are admitted to be heated and to flow blissfully from our pride, the smokeless stack. The proper method is to reduce the air supply until a faint haze is observed at the stack. This may at first seem difficult, especially with a large string of fires, but after a little practice an intelligent fireman will experience little difficulty even with a widely variable load.

In some plants the stack or breeching dampers are used entirely for air regulation, others use only the draught or ash-pit doors, and still others, a combination of the two. From a safety point of view the writer prefers either of the two last-named, although it must be admitted that the pressure drop in the furnace due to the resistance at the entrance will stimulate air leaks through the settings to a greater extent than would be the case should the breeching damper be used. But on the other hand, the draught doors are generally more accessible and more likely to be used and there is not so much likelihood of the dampers being entirely closed and the air supply shut off, for in this lies one of the greatest dangers. Should the breeching damper be closed while the fire is still on, the chances are that an explosion will occur, as the oil in the hot furnace will generate a large volume of volatile gas, which only awaits the admission of air to be ignited with disastrous results. To prevent the possibility of an occurrence of this sort, a safety stop should be placed so as to prevent the complete closing of the damper without removing the stop. A little common-sense applied at the right time will prevent nearly all oil-furnace explosions.—"Power."

Linking-up of Electricity Undertakings. — At a meeting held in Glasgow on November 3rd, when representatives from 15 electrical undertakings in the West of Scotland attended, it was decided to appoint a committee to discuss the question of linking-up electricity undertakings.

BOOK REVIEWS.

British Prices, Measures, and Weights converted into those of Belgium, France, Italy, Rumania, Serbia, Spain, &c., with some suggestions for Development of British Trade Abroad. By O. G. Winzar, F.S.M.C. London: Simpkin, Marshall. 8in. by 5in., 69 pp. Price, 2/6 net.

The war has revealed many defects in the national commercial equipment and none cause more trouble and annoyance than those arising out of our system of weights and measures and money values in connection with foreign trade. The differences in units of weight, length, and capacity are in themselves awkward enough, but coupled with differences in money values and variations in rates of exchange they become bewildering. After the war neutral countries will no doubt offer us exceptional trade facilities, but it will be impossible to take advantage of them unless we adapt ourselves to their requirements and offer our goods in the respective measures and currencies of the countries. This fact is well known, and in it lies the interest and value of this little book. Its scope is fairly indicated by the title and its merit consists in its simplicity and adaptability to commercial needs. The tables cover not merely the ordinary conversions, but practically all the money value conversions required in the counting house. The tables are well arranged, and plainly printed, and working examples are given in each case so that the reader need never be in doubt as to the method of using them. Such work requires a great deal of patient labour, and we heartily commend the book to the attention of our readers. All engaged in foreign trade will find it an invaluable companion for the office desk.

* * *

Soldering, Brazing, and Welding. By Bernard E. Jones, Editor of "Work." 78 illustrations, 154 pp. London: Cassell & Co., Ltd. Price, 1/- net.

This is an admirable little book on a subject which appeals to a multitude of readers, for although innumerable people can solder and braze after a fashion few can do it expertly and well, mainly owing to the want of a few simple instructions given in a practical, intelligible way. This information the book supplies and we compliment the author on the service he has rendered.

* * *

Telegraphy. A detailed exposition of the Telegraph System in the British Post Office. By T. E. Herbert, A.M.Inst. C.E., engineer, Post Office engineering department; 3rd edition. London: Whittaker & Co. 7½in. by 5½in., 986 pp. Price, 9/- net.

In the ten years that have elapsed since the first edition of this book was published great advances have been made in the science of telegraphy, and in the issue of the present edition the author has taken advantage of the opportunity to embody a description of these so as to bring it up to date. A detailed exposition of the British Post Office system it need hardly be said includes pretty near everything that is worth noting. The value of the book, however, does not consist merely in this, for throughout we note comments and reflections on the working of apparatus which can only spring from intimate practical experience and which to the reader or student are of great value. It is this feature, in fact, which gives the volume a special value, apart from the clear descriptions and excellent illustration afforded by the various diagrams. We ought, perhaps, to add that the book makes no attempt to deal with wireless telegraphy. The systems described relate entirely to telegraphy by conductors.

* * *

Specific Gravity Studies of Illinois Coals, Bulletin No. 89, issued by the Engineering Experiment Station, University of Illinois. London: Chapman & Hall. Price, 30 cents.

Experiments conducted at the Engineering Experiment Station of the University of Illinois have established a relationship between the ash content of bituminous coal and its specific gravity which makes possible rapid estimation of the ash and moisture content. These tests have also shown that a knowledge of the specific gravity of coal simplifies the problems of estimating tonnages underground and in storage, and of determining the adaptability of coal to treatment by the washing process. The experiments were made by M. L. Nebel.

* * *

Constructional Fire Stops on Passenger Ships. Report of the British Fire Prevention Committee, No. 205. Price, 2/6.

In July, the British Fire Prevention Committee issued report No. 203, dealing with the general question of fire protection for passenger ships. Having special regard to the fact that much shipbuilding work is under consideration, with a view to making good the wastage of the war, the committee have now issued this supplementary one which deals with the construction of passenger ships from the fire point of view with the specific intention of advocating sub-division of passenger ships and the use of fire-resisting materials so that a fire that has arisen at any given point may be more readily limited to a small area, much as water-tight compartments exist for limiting an area of submersion. The report comprises a chapter on fire compartments and one on fire-resisting materials, as also some useful appendices, one of which deals with certain features of the report of the Board of Trade Departmental Committee on Bulkheads, and another discusses the use of charcoal as an insulating material on board ship.

* * *

General Cargo : An Introduction to Salesmanship. By Richard E. Goddard. London: Constable & Co. 7¾in. by 5¼in.; 200 pp. Price, 4/6 net.

In his treatment the author does not attempt to reduce the art of salesmanship to cut and dried rules, for as those who have any experience of the matter must know such an expression of it is impossible. He does, however, give a number of hints and wrinkles which to anyone called upon to exercise persuasive influence in the disposal of goods should prove helpful.

BOOKS RECEIVED.

Stresses in Wire-wrapped Guns and in Gun Carriages. By Lieut.-Col. Ruggles, Ordnance Department, U.S. Army, formerly Professor of Ordnance in United States Military Academy. New York: John Wiley. London: Chapman and Hall, Ltd. Price 12/6 net.

Strength and other Properties of Concrete as Affected by Materials and Methods of Preparation. Technological paper No. 58, U.S. Bureau of Standards, Washington.

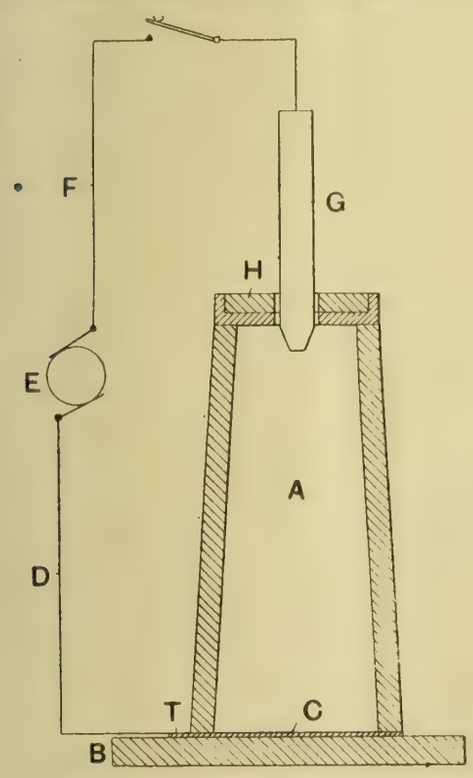
Manchester Association of Engineers.—At a meeting of the Manchester Association of Engineers, held on Saturday last, an interesting lecture was delivered by Mr. A. A. Barnes on "The Nile and the Utilisation of its Waters," which was extensively illustrated by lantern slides. Mr. Barnes indicated the outlines of the broad scheme whereby the waters of the river Nile are being controlled, by means of engineering works, for the purpose of irrigating Egypt and the Soudan. He dealt with the questions of the origin and regimé of the annual flood, the works necessary to protect Egypt from inundation, and the storage works for retaining a reserve of water to meet the demand of the crops in the summer months. The lecture was supplemented by an interesting selection of lantern illustrations, which had been obtained by the author personally during his recent travels in Egypt.

Federation of British Industries.—This Federation is intended to occupy itself mainly with the broader questions which affect the trade and industry of the country, and to represent British producers and manufacturers in much the same manner that the General Federation of Trade Unions represents organised labour. The Federation will not interfere with the normal functions of existing trade associations, but will support and strengthen them by every means in its power, in order that they may deal effectively with the particular problems confronting each individual trade. Its objects are the organisation and development of industry now and after the war, in co-operation with labour and in conjunction with the Government and Government Departments. A condition of membership is an annual subscription of £100 a year, with an obligation to continue such subscription until June 30th, 1919.

MOULD FOR THE PRODUCTION OF SOUND INGOTS.

A PROCESS has recently been devised and patented by Sir W. G. Armstrong, Whitworth, & Co., Ltd., of Elswick Works, Newcastle-upon-Tyne, in conjunction with Mr. E. F. Law and Mr. C. P. Sandberg, for the prevention of piping, blow-holes, or segregation in steel ingots or other castings, of the type in which the metal is maintained molten at the top of the ingot or casting by means of an electric arc of which the metal itself forms one of the electrodes, and is designed to obviate the difficulties hitherto experienced in removing the ingot from the mould caused by the fusion or welding of the ingot to the mould by the excessive temperatures reached locally, and which is especially the case in the method employing the electric arc in which a single carbon electrode is employed, the other connection being made to the mould itself. Owing partly to the shrinking of the ingot and partly to the nature of the surfaces, electrical contact is defective and resistance welding may occur between the two.

In the process under notice, ingots or castings free from piping, blow-holes, or segregation are formed by providing at



MOULD FOR THE PRODUCTION OF SOUND INGOTS.

the bottom of the mould a loose contact device which is connected to one of the electric leads and upon which the molten metal is poured, the other lead being connected to an adjustable electrode adapted to be brought into position above the ingot or casting to produce an arc between the top of the ingot or casting and the electrode.

The arrangement of the mould and its electrical connections are shown in the accompanying cut. At the bottom of the mould A, and resting on the base B, is provided a metal plate C, having a tongue T to which is connected one of the leads D from a convenient source E of electricity. The plate C may be made of steel, iron, or other suitable metal. The other lead F from the source of electricity is connected to an electrode G. A cover H is provided to prevent the escape of heat when the arc is in operation. When an ingot is to be cast, the contact plate C is placed on the base B, the mould A is placed in position and the metal is poured into the mould. As soon as possible after the mould is filled, the cover H and the electrode G are lowered into position over the top of the mould and the current is switched on. The current passes on the one hand through the lead D, plate C, and the metal of the ingot, which by partial welding is maintained in good contact with the plate, and on the other hand by the lead F and the adjustable electrode G, and an arc is formed between the molten metal at the top of the mould and the electrode. The heat produced thereby maintains the metal at the top of the ingot fluid until the rest of the ingot has solidified and so prevents the formation of pipes or blow holes and segregation. When the ingot has cooled, the tongue T is knocked off while the plate C, which is now firmly welded to the ingot and forms part of it, is removed with the "crop end" which is always cut off from the bottom of the ingot.

REFRACTORY MATERIALS.

DISCUSSION BY THE FARADAY SOCIETY.

AT a recent meeting of the Faraday Society a general discussion took place on refractory materials, which was opened with an address by Sir Robert Hadfield, F.R.S., the President, and reproduced in part as follows:—

Notwithstanding the fact that the satisfactory working of steel-making and other furnaces, as well as metallurgical operations generally, largely depends upon the correct kind of refractories employed, this important subject has not altogether received in this country the attention it deserves. There are about 200 makers of refractories in Great Britain, comprising about 140 in England, 40 in Scotland, and 30 in Wales; also about 12 makers of crucibles. The sources of raw products in this country are chiefly: (*a*) Derbyshire district; (*b*) Durham and Northumberland; (*c*) Lancashire; (*d*) Scotland; (*e*) South Wales; (*f*) Yorkshire (including Sheffield and Leeds); (*g*) Ireland (alumina, bauxite, and other products).

The following probably represent the chief refractories: (*a*) Silica; (*b*) china clay; (*c*) magnesite; (*d*) dolomite; (*e*) chromite; (*f*) bauxite; (*g*) graphite; (*h*) zirconite. There have been considerable imports into our country from abroad, when without doubt in most cases equally as good, if not better, material has been in our own country at our very door.

The great importance of obtaining a good refractory is shown by the fact that the first development on a large scale of the Bessemer process in Sheffield was chiefly because there happened to be in that city a particularly fine quality of material known as "ganister." Sir Henry Bessemer could not find material suitable for lining his converters, in which there is a combination of not only high temperature but slagging and erosive action. Sheffield ganister was found to meet this condition better than any other material, thus enabling Bessemer to carry his process into practical working success. The following is a typical analysis of ganister: Silica, 95 per cent.; alumina, 2 per cent.; iron oxide, 0·5 per cent.; lime, 1 per cent.; magnesia, 0·6 per cent.; water, 1·75 per cent. This material has been used for several generations to line the furnaces, known as "pot-holes," in which Sheffield crucible steel is made, and it is still unsurpassed for this purpose.

An important paper was read in 1912 before the Institution of Gas Engineers by Major Frederick J. Bywater, of Birmingham (now on active service), on the question of refractory materials. It may be stated briefly that Major Bywater considers the chief sources of refractory materials at present employed in the construction of retort settings are: (*a*) Fire clays; (*b*) silicious quartz. He gives an interesting résumé with reference to the origin of fire clays, their sources and composition, and points out that all the evidence collected tends to show the great difficulties encountered in attempting to establish a relation between the composition and fusibility of clays from investigations based on the ultimate analysis. In one case he quotes a particular specimen in which an analysis of a Stourbridge clay was quite satisfactory, yet this clay does not make satisfactory firebricks. In other words, tests which may be termed "mechanical" were made and the division of the material obtained into: (*a*) True clay substance; (*b*) quartz; (*c*) felspar.

Major Bywater describes the relative merits, as refractory agents, of the clay substance (or kaolin) and quartz, separated as above, and states that it has been found as the result of experiments by Bischof, Seger, and others, that alumina is slightly more refractory than silica, and that mixing silica and alumina in various proportions, the composition Al_2O_3; $2SiO_2$—*i.e.*, kaolin or true clay substance—is the most infusible. The addition of silica increases the fusibility until the composition $1Al_2O_3$; $17SiO_2$ in chemical equivalents is

reached; and with further increase of silica, the refractoriness rises.

The subject may be summed up in Mr. Bywater's words as follows: "It may safely be stated that the ultimate analyses of a clay, as usually employed, are of very little use in arriving at a proper estimate of refractoriness, and that far better knowledge is that based on mechanical and rational methods for subdividing it into its various mineralogical constituents, when ultimate analyses may be employed. Having arrived at a true knowledge of the constituents of the clay on these lines, samples and mixtures may be tested with success in a practical way in a small furnace."

Major Bywater points out that it is most important to have proper gas-testing furnaces, either coke or coal fired, and probably now electrical, for testing refractories. This furnace is of a type known as a modified Deville pattern, but since his paper was written Dr. Harker has devised a valuable electric furnace for dealing with the high temperatures in connection with experiments of this kind. This furnace should be of great service and give better results than either coal, gas, or coke-fired furnaces.

In one of the American papers reference is made to a simple but fairly effective method of testing refractory bricks, which has been brought forward by the Armstrong Cork and Insulation Company, of Pittsburg, Pa. Their experiment is carried out by playing the hottest flame obtainable, Bunsen burner or other gas jet, against the face of the brick to be tested. The surface naturally becomes white hot, but if the brick is not of the highest quality it will conduct the heat too quickly and soon become too hot to be held. This experiment could easily be carried out upon a brick of special qualities and a firebrick or common red brick, so that comparison is readily obtained. The maker claims that he produces these bricks chiefly from diatomaceous earth (in whose fronds are secreted very large quantities of silica), which he states is one of the best non-conductors of heat known. The exact nature of this earth is not mentioned, but no doubt before long it will be possible to obtain supplies in this country, so that tests can be carried out. It is claimed for this Nonpareil insulating brick that its insulating efficiency is ten times that of either common or firebrick, also that one 4½in. course installed in the walls, arches, and bottoms of furnaces, ovens, boiler settings, hot-blast mains, and kindred high-temperature equipment, will reduce the loss of heat as much as would 45in. of ordinary brick. This is a strong statement, but the firm seems willing to prove that it is correct.

In his justly renowned work on metallurgy, Dr. Percy devotes only a small space to refractory materials, including a portion of a chapter on fire clays. In this is given the following analysis, made in 1860, of the famous Dinas bricks: Silica, 97 to 98½ per cent.; alumina, 0·75 to 1·50 per cent.; protoxide of iron, 0·20 to 0·50 per cent.; lime, 0·20 per cent.

There are three classes of refractory materials now used for furnace linings: (*a*) Acid Dinas rock, ganister, fire clays; (*b*) Basic Dolomite, magnesite; (*c*) Neutral Bauxite, chrome, iron ore, graphite, and a few fire clays.

On satisfactory acid linings depend the acid steel process, such as the acid-Bessemer and acid-open-hearth. On satisfactory basic linings the success of the basic steel process practically depends, as in the presence of acid linings the necessary dephosphorisation cannot take place, any phosphorus oxide formed being converted and again deposited in the bath. Neutral linings, whilst possessing certain advantages, are usually very expensive and cannot be easily applied. On the other hand, in electric furnaces acid linings can be used if desired; nevertheless, basic, neutral, and zirconia linings are found to give much better results, hence the importance of a study of their application to this special purpose.

For crucible work there is still only the choice of two materials; the ordinary Sheffield clay crucible made of what is called pot clay, which is a mixture of fire clay, china clay, a little carbon, and sometimes small quantities of other special materials. The usual mixture is two-thirds raw and one-third burnt clay.

Plumbago crucibles are produced in large quantities, being composed of fire clay and graphite suitably mixed. The objection to the use of these crucibles is that naturally in melting steel considerable carbonisation often takes place, and material cannot be obtained of the same uniformity as that melted in the ordinary type of Sheffield crucible, which has been used ever since the time of Huntsman. It is an open secret that this is the reason for the uniformity of what is known as Sheffield crucible steel, which steel retains its position in the markets of the world.

Large quantities of millstone grit are found in the moor districts near Sheffield. Howe points out that in some cases blocks of millstone grit have been used with fair results.

In addition to the ordinary and well-known refractories in which silica and alumina play the chief parts, the somewhat rare product zirconia has recently received much consideration. In the interesting book published not long ago on "The Rare Earths," by Mr. S. I. Levy, B.A., B.Sc., a chapter is devoted to the study of zirconium and its oxides. In this reference is made to the importance of its use as a refractory. This oxide was isolated as a new earth from zircon, obtained from Ceylon by Klaproth in 1789. A little later the new earth was obtained also from hyacinth. The new oxide was examined in 1818 by Berzelius, who found it resembled alumina. The formula Zr_2O_3 was then given.

Whilst zirconium is fairly widely distributed in Nature, it is in very small quantities, and can be rightly classed as one of the rarer elements. The most important source of the element was until quite recently the mineral zircon with its gem varieties, hyacinth and jargon. The chief source of the ore at present is the naturally occurring oxide, baddeleyite, which is almost pure zirconia ($ZrO_2 = 96·5$ per cent.). This was discovered in 1892, particulars being given by Fletcher in the "Mining Magazine" of 1893. This has been obtained from the pyroxenite sand of Sao Paulo, South Brazil, also in Ceylon and in Montana, U.S.A. Its melting point is probably about 2,700° C., and at 3,000° C. it begins to volatilise.

Zirconia occurs in crystalline rocks, specially in granular limestone, schist, gneiss, syenite, and granite. The most frequent forms are the silicates of zirconium, $ZrSiO_4$. The chief localities are in alluvial sands in Ceylon, the Urals, in the gold districts of Australia, Brazil, and in many places in North America. It has been shown by Riecke in "Sprechsaal," 1908, No. 41, that whilst the oxide is very suitable for the manufacture of highly resistant crucibles and other refractories, its use is restricted by the fact that it is somewhat easily reduced by carbon at high temperatures, forming the carbide.

It appears that as early as 1904 the use of zirconia was suggested for cutting muffles, retorts, and tubes which are required to withstand high temperatures. It promises to be of the greatest use in all cases where a very refractory material, stable towards the ordinary chemical reagents, is required.

Metallic zirconium has also been obtained by the calcium reduction process, introduced by Kuzel and Wedekind. Whilst zirconia is not reduced by powdered aluminium (Goldschmidt's process), alloys of zirconium and iron can be easily obtained by reduction of the mixtures of the two oxides by this method. It appears alloys containing up to 35 per cent. of zirconium can be obtained; this ferro-zircon, as it is called, has been to some extent recently replaced by ferro-titanium for the purification of steels. Several German patents have been taken out for this purpose. It is also stated that any addition of small quantities of zirconium to steels (brass, copper, &c.), is said to secure sound castings, whilst increasing considerably the strength and resistance to acids of the metal.

The Foote Mineral Company of Philadelphia have paid a good deal of attention to zirconia, which, owing to its high degree of infusibility, high resistance to basic or acid slags, low thermal conductivity, low coefficient of expansion, they say can be employed at the highest temperatures without the destruction of the furnace linings. The material is supplied as zirconium oxide, also in the form of cement, affording a plastic bond when wet.

In addition to the excellent and complete set of exhibits from various members of the society, also other friends and firms, it had occurred to him (Sir Robert) that in these introductory remarks to the symposium of papers now presented it would be well to exhibit specimens of refractory materials, also those which were definitely known to have given good and bad results, with a view to obtain some discussion with regard to reasons for their respective satisfactory and unsatisfactory behaviours. A table giving a full description of these was presented, which showed that analysis only did not by any means tell all we wanted to know. Evidently there were physical conditions prevailing in these refractories which were not yet understood, just as in bars of the same steel and composition one might obtain good and bad tensile elongation

qualities, the causes of which, however, were now fairly well understood. Whilst, therefore, it was not analysis alone which would tell why one refractory was good and another bad, we had to look for the physical conditions of the respective combinations of the elements present, that was, apart from their chemical constituents. I therefore add the following information which has come to me from my company's laboratories in Sheffield. I give this fully because it represents the practical views of those handling daily various types and qualities of refractories.

Sand for Open-Hearth Bottoms, of which both British and Belgian specimens are submitted. Whilst Belgian sand for open-hearth furnace bottoms was in universal use before the war, when these supplies were stopped it was necessary to experiment with British sands. This was at first done by mixture with Belgian material, but ultimately a British sand has been found to give practically the same results as the foreign product since its properties were correctly understood. In this respect I would suggest that those in difficulty and doubt would often be able to obtain most interesting and valuable information from Dr. Strahan, the Director of the Geological Survey and Museum in Jermyn Street.

Silica Bricks.—One of the chief difficulties experienced with silica bricks is insufficient burning, known to furnace men as "half-bakes." Such bricks flux almost as readily as firebricks. If such bricks are not detected before putting in the furnace, it may mean shutting down the furnace for repairs, although the rest of the furnace is quite good.

Fire-clay Stoppers.—Stoppers are quite as important as nozzles. Magnesite does not appear to make a successful stopper as hitherto manufactured, owing to its liability to crack and spelch. When using magnesite nozzles it frequently happens that the fireclay stopper ends collapse during the casting, and fused pieces pass through the nozzles. Fireclay nozzles wear badly as compared with magnesite, and usually the orifice is double the size after similar work, which means that a good deal of silica has entered into the steel and is the cause of subsequent trouble.

Magnesite Nozzles.—Magnesite nozzles have given excellent results when used for a large number of castings from one heat, also with steels containing 0·90 per cent. of manganese and upwards. This is due to the fact that such steels have a severe chemical action on the fireclay nozzles. The use of magnesite for nozzles is not a new idea, but owing to the more stringent specifications in the manufacture of steel this use of magnesite is now being brought forward. One of our nozzle experiments was made with a combination of magnesite and fire-clay, but this was not successful, as the acid flux from the fire-clay attacked the magnesite and caused too much increase in the size of the orifice in the nozzle. It is also extremely important that these nozzles should be perfectly dry.

Plumbago Stoppers and Nozzles. A number of these have been tested and the results obtained so far have been no better than those with fire-clay.

Magnesite Bricks.—As is well known, this country was unfortunately, partly through ignorance and lack of enterprise, to some extent dependent upon Austrian magnesite. Supplies have also been obtained from Grecian mines.

Dolomite Bricks.—For use on the walls and roofs of electric furnaces, these would be invaluable if means could be devised to prevent perishing.

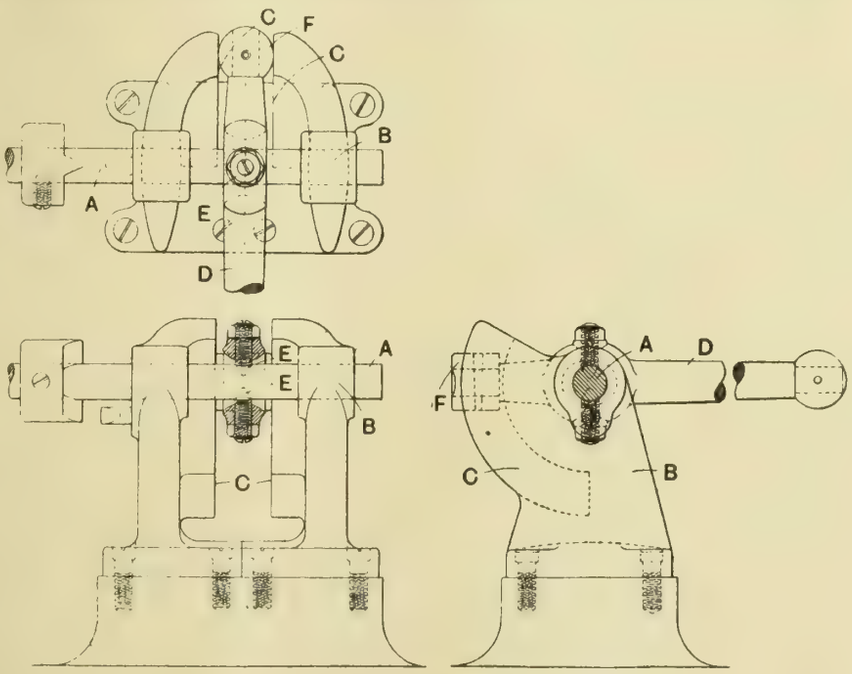
Zirconia.—Experiments are now in progress with this material, with regard to the practical application of which it will no doubt be possible to submit fuller information later on.

Conclusion.—This subject of refractories has been treated in the past far too much in an empirical manner. Whilst in this country much has been done from the time of Wedgwood and others, yet let us now show the world that we intend to lead the way and take up this important branch of metallurgy in a proper scientific manner. Much research is required in addition to that carried on at the works of the manufacturers. Research centres such as the National Physical Laboratory, the Metallurgical Section of the Sheffield University, and still more recently the Advisory Council for Scientific and Industrial Research, are all prepared to render help, either by carrying out actual researches or finding research grants to those they are satisfied will wisely spend such grants and make use of such information. It is to be hoped that this evening's symposium of papers will result in extended knowledge on this important subject. If so, the Council of the Faraday Society will be well repaid for the trouble they have taken in its preparation.

(To be continued.)

CONTROL MECHANISM OF BORING AND TURNING MILLS.

On many boring and turning mills one control lever is provided for bringing into operation either the fast or slow movement, and another lever is used for reversing the movement. On some boring and turning mills there are many other levers with the result that the control of the tool becomes very complicated. With a view to simplify the control, Messrs. Webster & Bennett, Ltd., Northey Road Works, Foleshill, Coventry, and Mr. Harry Thompson, have designed and patented the arrangement shown in the accompanying illustrations.



CONTROL MECHANISM OF BORING AND TURNING MILLS.

In this design the control is effected by a lever having a compound movement, motion of which in one plane engages the fast and slow motions of the mill, whilst motion in another plane controls the direction of such motions. Thus the operator can, without releasing the lever, control four different features of the mill. The arrangement comprises an actuating shaft A, which, when moved endwise in one direction, engages the fast motion, and when moved in the other direction brings into operation the slow movement. The shaft is also free to twist, and when twisted one way it causes the turret to move in one direction, and when twisted in the opposite direction it reverses the direction of its movement. Mounted around the shaft is a bracket B in which the shaft takes a bearing. This bracket carries curved guides C between which lies a cylinder F on a lever D. The lever is pivoted on the shaft A by a pair of pointed pins E engaging radial recesses in the shaft, so set that the lever is free to rock about the axis of the shaft, at the same time twisting the shaft with the end F sliding in relation to the guiding surfaces. This motion controls the feed and reverse. The lever can also rock longitudinally with regard to the shaft, its fulcrum being its point of engagement of the part F with the guiding surfaces C. When rocked in this manner the shaft is moved longitudinally and the fast and slow motions are thus controlled. With this arrangement a simple lever controls the four most important movements of the machine, movement in one plane operating the fast and slow motions, and that in another plane controlling the direction of such movements.

STEAM-FLOW MEASUREMENT.*

BY ERVIN G. BAILEY.

(*Concluded from page 365.*)

The Ledoux Liquid-sealed Bell for Measuring Small Pressure Differences.—Of the three principal methods usually employed to measure small pressure differences, viz., U-tube, diaphragm, and liquid-sealed bell, the latter has been found to be the most satisfactory. It is on the same basic principle as a piston which gives a force proportional to the area times the difference in pressure applied to its opposite sides, but by sealing the walls of the bell in a liquid, instead of confining the piston to a cylinder, it is made substantially frictionless in its operation. Futhermore, by varying the relative cross-sectional area of the bell and its walls, any complex relation between pressure difference and bell motion may be readily obtained.

A very ingenious and thoroughly practical design for flow-meter work has been described by J. W. Ledoux. This can be briefly explained by referring to Fig. 6, which shows a typical flow curve and a liquid seal bell of this type in five different positions corresponding to as many rates of flow equally spaced

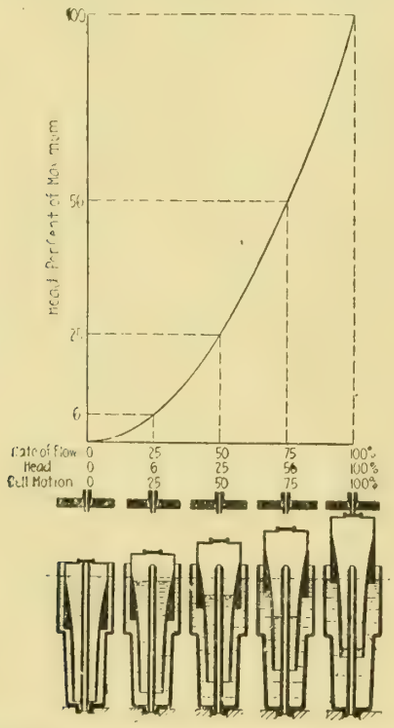


FIG. 6.—PRINCIPLE OF LEDOUX LIQUID-SEALED BELL.

between zero and 100 per cent., inclusive. In the zero position the bell is held almost completely submerged so that the large effective area and the thin wall are at the surface of the mercury. The increment of pressure difference corresponding to the first appreciable rate of flow is very small, but this is effective over the entire area of the bell, forcing it upward, and as the bell rises its walls emerge from the mercury, changing the buoyant force, thereby exactly counteracting the upward force due to the pressure difference. A rate of flow of 25 per cent. corresponds to a head of only 6 per cent., so that the relation between bell area and wall gives a very powerful and magnified motion which is directly proportional to the rate of flow, and therefore amounts to 25 per cent. of the total bell motion allowed for in the design. And so on, each step may be followed, showing that the motion of the bell is directly proportional to the rate of flow, and that the device is not only one easy to read and which permits integrating mechanism to be used with a simple design, but one which has also greater power at the lower rates of flow and produces a very satisfactory degree of accuracy. An interesting feature of this bell is that the volume of mercury displaced on its interior side by the difference in the level of mercury, exactly equals the volume of the walls in the bell which are forced out from the mercury, so that the mercury level in the containing reservoir is substantially constant. The higher and lower pressure connections terminating within and above the bell respectively are so positioned that a soft packing filler piece will engage and seal either of these when an extreme position is taken. This effectively seals either outlet, and as the entire mechanism is enclosed in a steam-pressure tight casing and completely filled with water, no mercury can be blown out or the accuracy of the mechanism impaired through excessive pressure differences caused either by abnormal rates of flow, faulty manipulation of the valves, or even the breaking of one of the two pressure connecting pipes. Fig. 8 shows one application of the Ledoux bell to a recorder.

Measurement of Pulsating Flow.—The question of measuring steam to reciprocating engines, pumps, &c., has been somewhat misunderstood. Many engineers have the impression that the pulsations cause an unduly fluctuating motion of the recording or integrating mechanism so that accurate results cannot be secured. But such is not the case except in very slow speed pumps. It is also wrong to say that a flow meter is inaccurate for measuring pulsating flow, for the present flow meters will produce accurate results when more knowledge is gained along this line. Steam flowing to a reciprocating engine follows some such variations as are shown in Fig. 8, the exact nature of the curve depending upon the cut-off capacity of the steam line between the orifice and the engine, and some other factors. At any rate of flow there are very great and frequent variations in the rate of flow which occur periodically and yet so rapidly that no recording meter could possibly follow them individually. In fact, the inertia of the water columns in the connecting pipes to the recorder, together with the mercury in the U-tube, bell float, or other mechanism, is so great that no appreciable motion results from the individual pulsations, but rather the reading is an average of the head or pressure difference resulting from such flow. Regardless of the use of cams, special-shaped bells, displacing members, or any other mechanism whereby a motion is produced in direct proportion to the rate of flow, for continuous flow they cannot possibly produce an average reading that is directly proportional to the rate of flow in the case of pulsating flow.

In Fig. 8 the parabola shows the characteristic relation between rate of flow and pressure difference with 100 per cent. flow at 100 per cent. head. Assuming that the rate of flow varies from zero to 100 per cent., the nature of the cycle being no flow during 50 per cent. of the time and 100 per cent. flow during the other 50 per cent. of time, then the average flow would be 50 per cent. At the same time, the pressure difference varies in like manner from 0in. to 50in. water head, with an average of 25in. The inertia of the meter mechanism produces a reading corresponding to this average pressure difference of 25in. instead of an average reading of 50 per cent. on the quantity scale. The reading on the quantity scale corresponding to the average head of 25in. is 70·7 per cent. This 70·7 per cent. divided by 50 per cent., which is the true average flow, gives 1·42, or a reading 42 per cent. higher than would be the case if the same amount of steam were flowing at a continuous rate. This ratio has been termed the "pulsating factor," and while it might be calculated on a theoretical basis from the nature of the flow curve, if it were known, yet it is better to determine it by actual calibration; and if so determined the steam-flow meter can operate as satisfactorily on a reciprocating engine as on a continuous flow to turbines, heating systems, &c. It should be remembered that the pulsating factor may not be the same at all different loads of the engine. It is, however, a function of the load for any one engine so long as the valve adjustment, &c., remain reasonably uniform.

The problems in connection with pulsating flow that are most difficult are those in which there is a mixture of pulsating and continuous flow, with no definite ratio or relation existing between the two. An example of this would be a steam line supplying both an engine and a turbine. Another case where the pulsating effect has been encountered was in a steam line leading from a main header to a heating system where a reciprocating engine also drew steam from the same header. Even though the orifice of the flow meter was in the branch line leading to the heating system alone, yet the intermittent flow of steam to the engine caused a fluctuation in the steam pressure in the header. This fluctuation in static pressure caused a fluctuation in the rate of flow of steam to

* Abstract of paper presented at a meeting of the Boston section of the American Society of Mechanical Engineers, May 23rd, 1916.

the heating system from this header, with the result that an erroneous reading might have been obtained if the meter had not been calibrated under such operating conditions. The pulsating factor may sometimes be eliminated by throttling between the orifice and the source of pulsation.

Calibration of Steam-flow Meters. It is desirable to have a ready means for calibrating steam-flow meters in place as

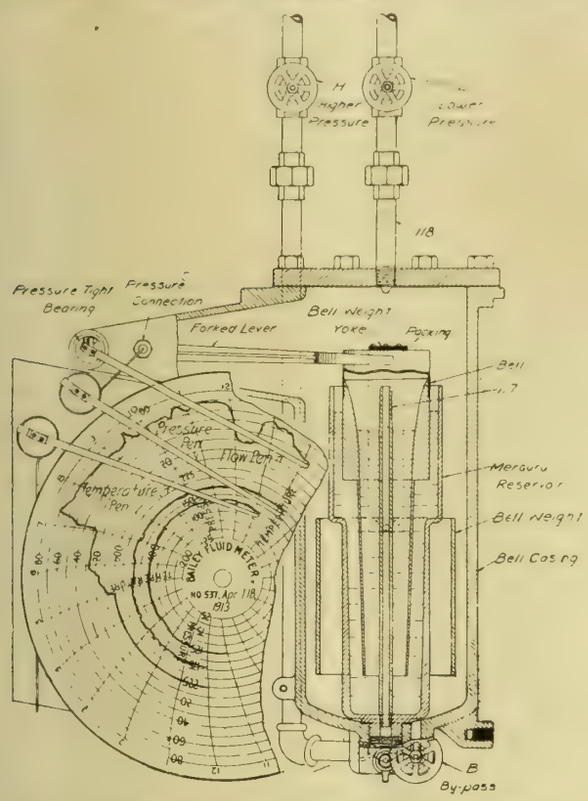


FIG. 7.—DIFFERENTIAL PRESSURE RECORDER, LEDOUX BELL TYPE.

it is for wattmeters, pressure gauges, thermometers, &c. It has, heretofore, been considered necessary that steam flow meters be calibrated by passing all the steam through a turbine to a surface condenser that is known to be tight and free from leaks. This latter point can be well taken care of where sea water is used for circulating, but is often difficult where fresh water is used. The other method is in weighing water to a boiler from which all the steam passes through the meter being calibrated. In this case it is necessary to guard against leaks from the feed line blow-off, or branch steam lines. An additional difficulty arises in the boiler method, which is in having the same amount of water in the boiler at the end as at the beginning of the test. The fact that the water level is brought to the same mark on the gauge glass is not positive evidence that the water in both drums, or even different parts of the same drum, is at the same level. But a still greater source of error along this line lies in the volume of steam beneath the water level, which is greatly affected by rate of steaming. Some tests on a 500 h.p. Babcock & Wilcox boiler have shown that the volume of steam beneath the water level varies as much as 50 cub. ft.

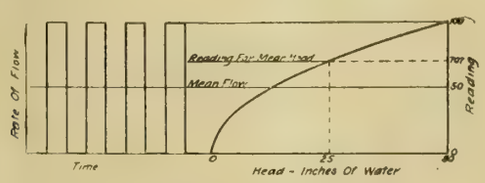


FIG. 8.—EFFECT OF PULSATING FLOW.

with a change in the rate of steaming of 14,000lbs. per hour. That is, the boiler was steaming at the rate of 24,000lbs. per hour at the beginning of the hour, and at 10,000lbs. per hour at the end of the hour; there were 11,500lbs. of steam generated during the hour, but it was necessary to feed 14,750lbs. of water to the boiler during this period to maintain the water level at the same point in the gauge glass. This means that 3,250lbs. of water, or over 50 cub. ft., were required to fill the additional space occupied by the steam below the water level at the higher rate of steaming as compared with the lower rate. This is a source of error that cannot be overcome or corrected except by continuing a test over a long period of time and ending the test with the same rate of steaming as at the beginning.

CO_2 Method of Steam-meter Calibration. In case of weighing water either to a boiler or from a surface condenser, it is necessary to put in large weighing tanks and scales and often make very costly changes in the feed line or steam piping, so that a diligent study of this problem was made to find a better method of steam calibration-meter. The method worked out by the writer consists in introducing CO_2 gas from a high-pressure drum into the steam line at a known and continuous rate, permitting it to mix with steam, then drawing out a sample, condensing the steam and determining the ratio of condensed steam to CO_2 gas.

TABLE I.—*Summary of Data comparing Steam Measurement by CO_2 Method with Actual Weight and Steam-flow Meter, Orifice Type.*

(Made in connection with evaporation tests on a 512 h.p. B. & W. boiler.)

Duration of test, hours.	Water fed to boiler by actual weight, lbs.	CO_2 fed per hour, lbs.	Ratio water to CO_2.	Steam by CO_2, lbs.	Steam by meter, lbs.	Difference between CO_2 method and Actual weight, per cent.	Difference between CO_2 method and Steam meter, per cent.
4	—	8·64	2,548	90,500	91,620	—	−1·22
2·5	78,515	8·53	3,645	77,650	78,040	−1·10	−0·50
6	133,474	8·68	2,506	130,500	129,190	−2·26	+1·01
3	54,505	14·63	1,276	56,000	55,830	+2·78	+0·29
9*	187,979	—	—	186,500	185,020	0·78	+0·80
5	132,667	8·85	2,992	132,130	133,650	−0·40	−1·14

* This line gives the sums of the two runs directly above.

In the first experimental work along this line the attempt was made to determine this ratio by considering the CO_2 as

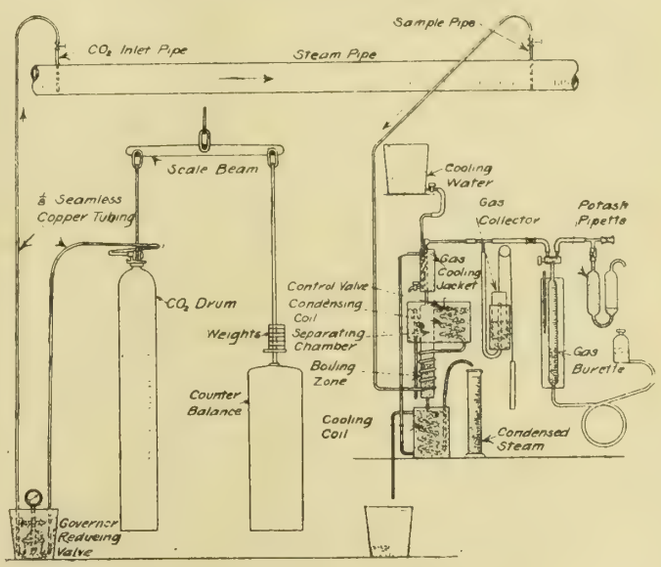


FIG. 9. -CO_2 METHOD OF STEAM MEASUREMENT.

carbonic acid in solution and titrating for the amount of it contained in the condensed steam by the use of chemical means. Some rather erratic and unexpected results were at first obtained from this titration method, and in an effort to check up this method another more valuable feature was worked out whereby the gas was thoroughly separated continuously from the condensed steam and the two measured separately. The general diagrammatic arrangement of the apparatus used in this method is shown in Fig. 9.

This method is based upon the addition of CO_2 gas from a high-pressure tank or drum to the steam line at a continuous and known rate. The gas becomes thoroughly mixed with the steam as it passes along, and a sample, consisting of a mixture of steam and CO_2 gas, is drawn off continuously from a point further down the line. The steam in the sample is then condensed, the gas and water are thoroughly separated and each measured so as to determine the ratio of water to

gas. This ratio multiplied by the rate at which the gas was added will give the rate of flow of steam.

The drum containing CO_2 gas under high pressure is supported on a scale beam so that its weight can be determined at any time, from which the rate of adding the gas is accurately determined. The gas is continuously discharged through a flexible copper tube and a governor valve into the steam line through a ⅛in. spray tube. A sample of the mixed steam and gas is taken from the steam pipe at a point further down the line. The sample is then passed through a condensing and separating apparatus and the condensed steam and gas are measured separately in a graduate and Hempel burette, respectively. The entire operation is continuous, except that these two measurements are taken simultaneously at regular intervals of four to five minutes.

An accuracy of 1 per cent. to 1½ per cent. can be secured when using only 1lb. of gas to 2,000lbs. of steam. Hence, it is possible to use this method on large capacities up to several hundred thousand pounds of steam per hour. Some data are given in Table I. This method has also been tested out for measuring the flow of water, the gas being injected into the feed line, and with the small ratio of gas required the CO_2 is completely absorbed by the water so that a representative sample is readily obtained. The gas is then completely separated from the water and the ratio determined by the measurement of each.

It will be noted that this method is entirely independent of steam pressure, superheat, or percentage of moisture, and it resolves back to an actual weight basis. It requires no change in piping except to drill and tap for ⅛in. pipe at two places. It is particularly adapted for test work in calibrating meters, determining steam consumption of turbines, engines, pumps, auxiliaries, &c., but does not take the place of a permanently installed recording or integrating meter.

IS SULPHUR INJURIOUS TO STEEL?*

BY CARLE R. HAYWARD.

SULPHUR has long been one of the banes of the steel manufacturer, and often no effort or expense have been spared in order to reduce it to a small per cent. in the finished product. This condition is due to a general conviction that in many cases where steels have failed in service, sulphur has been the cause. But there has been a growing feeling in recent years that the verdict against sulphur has been unnecessarily severe. In cases of segregation it was present in augmented amounts along with other impurities, but it had not caused the segregation. High sulphur in pig iron is caused by poor furnace conditions and the sulphur is merely one indication of an iron that has not been properly reduced. No amount of subsequent treatment under oxidising conditions in the open-hearth furnace can remedy the defects, although the per cent. of sulphur may be considerably reduced. In other words, the causes of bad steel can frequently be traced back to bad pig iron, and sulphur is merely one indication that the pig iron is bad. The writer recently visited a steel plant where a mass of evidence had been accumulated which substantiated this fact, and the superintendent was emphatic in stating that high sulphur was not harmful provided the steel was not otherwise poor due to insufficient reduction in the blastfurnace.

The presence of a moderate amount of sulphur is desirable from the standpoint of the man who machines the steel. The low sulphur material drags and the production of a smooth surface is very difficult. A slight increase in sulphur enables the machinist to produce a smooth surface without difficulty. Since, therefore, such large quantities of steel are subjected to machining, it becomes highly important that the sulphur controversy should be settled, and if its presence is proved to be harmless the ban on it should be lifted.

Among the recent papers on the effect of sulphur on steel is one by Dr. J. S. Unger, manager of the central research bureau, Carnegie Steel Company. The results of an exhaustive series of tests are given and the conclusion states: "The author does not advocate paying any attention whatever to sulphur content in steel, but believes firmly that a steel containing less than 0·100 per cent. is not necessarily bad, and that it will show little, if any, difference in quality when compared with the same steel of much lower sulphur, other conditions being the same."

The present investigation was undertaken at the suggestion of A. H. Annan, of the Rhode Island Tool Company, who co-operated by furnishing the steel and machining the specimens. The results are presented as a contribution to the general knowledge on the subject. It was planned to use three steels, of different sulphur content, but with the other elements the same. The manganese was an exception, however, for with this element part is in the form of MnS existing free in the steel and the remainder is dissolved in the steel. It is evident, therefore, that the manganese should vary but that the amount in excess of MnS should be constant in the different steels. The steels finally selected were in the form of ¾in. round bars. Two bars of each grade were required to furnish sufficient specimens. The analyses are shown in Table I.

In order to make a comparison of the steels under different conditions it was decided to heat all the specimens to a temperature just above the critical range, quench in water, and reheat different lots to 300°, 400°, 500°, and 600° C., respectively. For this purpose the bars were cut in 7in. lengths, which was sufficient for tensile specimens and specimens for microscopic examination.

The furnace used is shown in Fig. 1. The muffle is made

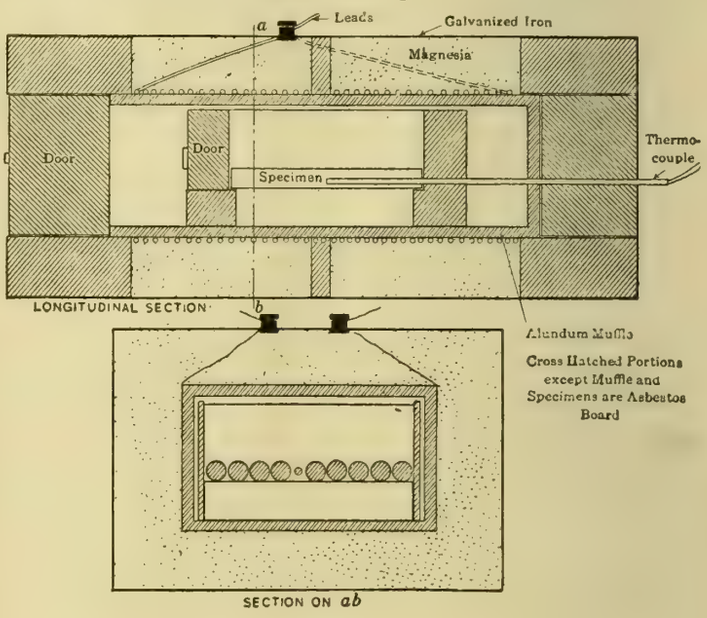


FIG. 1.

of alundum and is 2in. high, 9in. wide, and 16in. long. It is wound with No. 15 excello resistance wire. In order to maintain uniform heating of the specimens, they were supported on an asbestos rack, as shown. Asbestos shields were placed on the sides and ends of the rack so that the specimens in the furnace were practically in a muffle within a muffle. A platinum, platinum-rhodium thermo-couple was introduced through the back of the muffle into the centre of the heating chamber and connected to a Siemens and Halske recording galvanometer.

TABLE I.—*Analyses of Test Steels.*

Carbon, per cent.	Total Manganese, per cent.	Excess Manganese, per cent.	Phosphorus, per cent.	Silicon, per cent.	Sulphur, per cent.
0·18	0·55	0·48	0·007	0·01	0·038
0·18	0·57	0·50	0·009	0·02	0·041
0·17	0·67	0·52	0·008	0·01	0·086
0·18	0·70	0·55	0·010	0·03	0·087
0·18	0·80	0·54	0·006	0·02	0·152
0·17	0·80	0·55	0·011	0·03	0·148

The procedure in heat treatment was as follows: The furnace was heated to 880° C. and nine specimens introduced. This caused the temperature to fall to 550° C., and it took about 40 minutes to again reach 880°. When the latter temperature was reached it was maintained constant for 15

* Abstract of paper to be presented at the New York meeting of the American Institute of Mining Engineers, February, 1917.

minutes, after which the specimens, except as noted below, were quenched in water and a new lot introduced into the furnace. This was continued until all but 18 of the specimens had been treated. Nine of these, consisting of three high, three medium, and three low sulphur steels, were removed from the furnace and allowed to cool in air. The remaining nine, consisting of three of each sulphur content, were allowed to cool in the furnace.

In drawing the quenched specimens at the various temperatures, the procedure was as follows: The furnace was heated to 600° C. and nine specimens, three of each sulphur content, were introduced. The temperature fell and it required about 30 minutes to come back to 600° C. It was maintained here for 10 minutes and then the specimens were withdrawn and quenched in water. The furnace was cooled to 500° C. and another set of nine specimens was introduced. When the temperature had regained 500° C. it was maintained constant for 10 minutes and then the specimens were withdrawn and quenched. Following a similar procedure, sets of nine specimens were treated at 400° and 300° C. respectively.

After sawing off ¾in. from each piece for microscopic examination, standard test specimens were prepared with 2in. gauge length, 0·505in. diam. and threaded ends. These were pulled in an Olsen machine in the testing laboratory of the Massachusetts Institute of Technology. After concluding the tensile tests it was thought desirable to determine the effect of varying sulphur content on specimens subjected to shock. Through the kindness of the testing department of the Watertown arsenal, the use of the Charpy machine was obtained for this purpose. The remaining ¾in. stock of the bars was sawed into 2in. lengths and the specimens subjected to heat treatment in sets of three under the same conditions that obtained in the case of the tensile specimens. After heat treatment, the specimens were machined to conform to the following specifications: Length 55 mm, cross-section 10 by 10 mm., notch across one side, midway between the ends, 1 mm. wide. Radius of cutter edge, ⅔ mm.

The Charpy machine consists of a heavy pendulum which drops from a fixed height, strikes the specimen supported at each end, and breaks it at the notch. The pendulum then continues its swing and the height it reaches is registered. Knowing the weight of the pendulum, the height it falls, and the height it rises, a simple calculation gives the energy consumed in breaking the specimen.

Conclusions.—The results of the tensile tests show that the sulphur does not lower the tensile strength. The figures obtained for elongation and reduction of area show that there is little difference in ductility between the low and medium sulphur steels, but the ductility of the high-sulphur steel is slightly lower than the other two for most of the treatments. The average figures for the shock tests, except for the air and furnace-cooled specimens, are highest for each treatment in the case of the low-sulphur steels and lowest for each treatment for the high-sulphur steels. The widest difference appears in the steels which were quenched and reheated.

It is difficult to draw definite conclusions from the results because of the newness of the shock test and the difference of opinion among engineers regarding its value. The tensile tests are not unfavourable to steels with moderate amounts of sulphur, while the shock tests show a decided falling off in strength as the sulphur increases. Until the interpretation of the results from the Charpy machine is more fully understood, it is impossible to say to which set of tests the most importance should be attached.

Further light might be thrown on the subject by making alternate stress or fatigue tests. It would be important to learn whether the results would confirm the tensile or shock tests. Unfortunately, however, the stock of steels used in the previous work was exhausted, and whatever the results of the fatigue tests there would be an uncertainty in their interpretation because of difference in stock. It was therefore decided not to include this series in the present investigation.

New Walsall Electricity Station. — The new electricity generating station which has been erected for Walsall Corporation at an approximate cost of £75,000, on a site at Birchills, was formally opened a few days ago. Within the past two years as a result of the war Birmingham has increased its output from 80 millions to 150 millions of units.

THE INSTITUTION OF CIVIL ENGINEERS.

PRESIDENTIAL ADDRESS.*

IN casting about for a subject on which to address you to-night, I felt at first that it might be of interest to take up the thread of the presidential address in 1883 by the late Sir Joseph Bazalgette, the engineer to the Metropolitan Board of Works. For many years, as engineer to the London County Council, I occupied very much the same position as he did, and I thought it might be useful to look into the development of London from an engineer's point of view during the period which has elapsed since his remarks were made on that subject.

The alterations in London since his time have, of course, been enormous, particularly in the fascinating question of facilities for traffic. At the date mentioned tube railways, motor 'buses, and taxicabs had not arrived. The first electric tramways in Great Britain came into operation in that year, but not in London. Unless one compares old and new maps it is difficult to realise the extent of streets widened and new streets constructed during a period of over 30 years. Electric lighting and telephones were only just coming into general use. In other services, such as water supply and drainage, the improvements since Sir Joseph Bazalgette's time have more than followed the increase in population. In fact, on looking into the matter I came to the conclusion that the subject, if treated as it deserved, was much too vast for a presidential address. I have, therefore, ventured to content myself with a much smaller subject, and, with some diffidence, I propose to deal in a general way with some very elementary questions which have presented themselves to me in connection with those branches of engineering in which I have been particularly engaged. I am going to say a few words to-night about some of the reasons which at times prevent success in engineering.

There are two kinds of want of success which I propose to consider—that in connection with works and that in individuals. There is a third class which some of us have experienced, namely, want of success in undertakings owing to the financial arrangements coming to grief; but this class, although very disconcerting to engineers, is not so clearly allied to our profession as the two former.

I do not suppose there are any engineers in this room who have carried out undertakings of any extent who have not had, at some time or other, to lament failure or accident in connection with at least some part of their works. For many years I was fortunate enough to be engaged by some of those great engineers whose portraits we see surrounding us, and I cannot recollect any large undertaking which has not at times caused my chief considerable anxiety owing to accident on some portion of the works, or from alteration in design having to be made on account of unforeseen causes. Since I have been carrying out works on my own responsibility I have found a similar state of affairs, and I believe all engineers have from time to time experiences of a like kind.

I am not now speaking of great calamities or disasters such as the failure of the first Quebec Bridge, the first attempt at constructing the Panama Canal, the failure of the old Tay Bridge, that of the first attempt at constructing the Hudson Tunnel, or the complete failure of some reservoir dams. I am referring to those misfortunes which happen more or less on all works of engineering construction.

Although very often not of great magnitude, they cause the engineer, the contractor, and client great anxiety and disappointment. The engineer in the case of accident causing loss of life, even although it may be in connection with temporary works for which he is not directly responsible, feels it very keenly, and probably thinks he might have taken, or caused to be taken, some precautions which would have prevented it. Although even a serious accident on works may not entail any extra cost to the engineer's client, it may necessitate such an addition to the time of construction as will seriously dislocate arrangements made for the use of the works, and may in that way be a cause of serious financial loss.

The necessity for alteration of design, or part of design, owing to unforeseen difficulties, is generally a matter which

* Delivered by Sir Maurice Fitzmaurice, C.M.G., M.A., M.A.I., LL.D., November 7th, 1916.

causes much anxious thought and trouble to engineer and client. Unfortunately, alteration in design is generally accompanied by increased cost and time. In exceptional cases unforeseen difficulties may necessitate abandonment of the work.

The question arises, are engineers, as a rule, too optimistic in designing their work, and in their estimates of time and cost? This question, however, only deals partially with the class of failures I am considering, and before going further I want to clear the ground in connection with one important point.

Works of any size are generally carried out by contract, and the contractor employed has a very important bearing on the question. Probably every engineer would like to choose as contractor for any work which he has to undertake that firm which has previously carried out similar work for himself, or for engineers he knows. This course is, however, one which cannot be adopted, except in a few special cases, owing to obvious reasons.

As is well known there are two ways of obtaining contractors for works, either by open tender or by asking selected firms to tender. In the first case it is generally understood that it is quite allowable not to accept the lowest tender if the firm has not the necessary experience and standing. There are, however, very often considerable difficulties in rejecting low tenders of unsuitable firms, and explanations to clients are often difficult. I have had experience of a firm tendering for work approximating in value to one million sterling who had no experience of the class of work tendered for, but whose financial and other references were good. Fortunately, the tender was passed over. Later on, when the same firm obtained a small contract for somewhat similar work, amounting to about £35,000, failure took place before the work was two-thirds completed. I only mention this as an example of some of the difficulties which arise in open tendering. It is often very difficult to judge of the financial position and the capabilities of a firm of which one personally has no knowledge. Sometimes those who are given as financial and general references seem to rather more than stretch a point in favour of the firm enquired about, or the answers given are so vague as to be useless.

It might be considered that all difficulties could be avoided by asking selected firms to tender, and in such cases it is generally understood that the lowest tender will be accepted. The procedure is, however, often not satisfactory. It frequently happens that the client wishes to include in the selected list the name of a firm who has carried out to his knowledge some work in a satisfactory way, although of quite a different character to that being dealt with at the time. This is often the cause of great trouble to client, engineer, and contractor.

We all know contractors whom we would cheerfully accept without any question of reference, firms who at an early stage of the work recognise the necessity of a good staff and of providing all necessary plant and who know that the initial cost thereby incurred is more than regained by the facilities obtained in carrying out the work and by the saving resulting from curtailment in time of construction. It is probably due to the well-deserved profits made by such contractors that other firms without the necessary capital or experience are frequently tempted to tender for work which they are not capable of carrying out with satisfaction to the engineer or his client, or with profit to themselves.

It must not, however, be assumed that I am favouring in all cases the employment of the large contractors. I have had considerable experience with contractors in quite a small way of business who carry out the smaller contracts entrusted to them in a thoroughly satisfactory way, especially when they have laid themselves out for only one or two classes of work, when the principal can give personal attention to the matter, and when they resist the temptation to embark on undertakings beyond their capacity. Some of my most pleasant experiences in engineering work have been with such firms.

I do not know any more unpleasant position, both for contractor and engineer, than when it is evident that a contract is being carried out at a loss. In such cases the contractor, on the one hand, may be forced to carry out the work in a slow and unsatisfactory way, and the engineer, on the other hand, feels that he cannot well press the contractor to spend more money on plant and staff.

I have very shortly mentioned these difficulties with contracts, as they are a source of real trouble, but I think I ought at the same time to acknowledge the great help which engineers obtain from many contractors. I consider that one of the most pleasant features of our profession in this country is the friendly and helpful feeling which generally exists between engineers and contractors. This is only to be expected when we know that many contractors and a large number of their assistants are connected with this institution.

I now come back to the question whether engineers as a rule are too optimistic in designing their work, and in their estimates of cost and time. On full consideration of the matter I am inclined to think that we must sometimes plead guilty to this charge, although the optimistic view and underestimates of cost and time are not always willingly arrived at. I do not know whether my experience on this point is the same as that of other engineers.

I am well aware that even in works where all the details have been worked out with the greatest care, where unit prices have been carefully scrutinised, where the different stages of the work have been well thought out, where all possible local information has been obtained, that even then it is necessary to provide a sum of money over and above the detailed estimate to meet any contingencies which may arise, and to make some addition to the estimated time for construction. In some cases, when adopting this course, I have been met with the statement, particularly when dealing with some Government or municipal authorities, "You surely, if the design has been properly gone into, do not require that large sum of money for contingencies"; or, "Surely you can cut something off the estimate for time of construction" One then explains the reason of money for contingencies and the added time for construction. After some discussion the client says, "Well, what it comes to is that if everything goes well the contingency money might be materially decreased and the time for construction reduced, and I would prefer that we took the risk of cutting both down." The engineer knows from experience that such a course is not wise, and that if things do not go right the conversation will probably be forgotten, but very reluctantly finds himself forced, in some cases, to reduce his estimate of money and time.

What are the reasons why engineers frequently find that their most carefully made estimates of both cost and time are exceeded? The principal reason is, I think, given by the hackneyed but true phrase which we often hear, that engineering is not an exact science. We are continually finding out more about the forces of nature, but as long as the world exists we shall not find out sufficient to enable us to make exact estimates of time and cost, and guarantee works against accidents.

What, shortly, are the principal matters which cause us trouble? The first one, in my opinion, is the small knowledge we are able to obtain of the conditions which exist below the surface of the earth on which everything has to be founded; secondly, the risk which it is necessary to undertake as regards conditions of weather while works are being carried out; and, thirdly, the varying quality of many of the materials we have to deal with. There is a fourth matter, which affects contractors more than engineers, namely, the difficulty of estimating the cost of materials and rates of wages for a long time ahead. This last also substantially affects engineers' estimates when there is a long interval between the time when the estimates are made and that when tenders are received.

As regards the first of these matters, we, in most cases, try to obtain all the information possible about the nature of the ground we have to deal with by making borings. It is commonplace to remark that the information obtained from borings is not always reliable, particularly when the ground is of a variable character. It is true that with certain classes of boring machinery, particularly when in rock, we can obtain cores which give information of great value. In many cases, however, it is very difficult to form a just estimation of the ground when the material has to be broken up by the ordinary drill before being brought to the surface. After all information has been obtained by borings, the fact remains that all we have is a rough idea of the nature of the ground at the exact spot where the boring has been made. In many cases, if one goes 50ft. north, south, east, or west, very different information is obtained. I am sure we have all had experience of being deceived by borings I know of a recent

case where a series of borings was put down for a wharf wall at short intervals on the line of the wall, both back and front, and what was considered to be the level of solid clay was established. As the work proceeded, however, it was found that deep pockets of mud, going to a great depth, existed between some of the borings. There have been cases of railway cuttings where the borings made to disclose the level of the rock, unfortunately, went into pockets of soft mud, and I have known one case of that kind where the cost of a very large cutting eventually came to more than double the estimated cost. My partner, Sir William Matthews, when recently referring at this institution to borings put down with the greatest care for the outer barrier, Hodbarrow, said, "If the engineers had purposely placed the borings so as to deceive the contractors with regard to the level of the clay bed, he did not think they could have placed them in better positions."

Such cases could be multiplied at will, and it is quite obvious that borings cannot be made at such close intervals as will disclose, as far as borings can, the nature of all the ground that has to be dealt with.

Then there is the important point that even if by borings the nature of the ground be disclosed, we obtain very little information as regards the quantity of water which may be met with, the dealing with which may be a very important item, both in the cost and time of the undertaking. I was recently pressed very hard by a client to state from borings whether it were possible to construct a graving dock on a certain site. I knew from the borings that water was found all over the site, and although the levels and character of the water did not help me much, it seemed more than possible that there might be direct connection with a large adjacent expanse of water. I had to say that I was unable to answer the question, and that the only way I could suggest to obtain an answer was to sink a shaft for 50ft. down from the surface of the ground and find what pumping power was necessary, taking also careful notes of the material found as the shaft was sunk and the effect, if any, of the pumping on the adjacent ground. My last information was that a very large number of pumps had been employed, that the shaft had been got down about 25ft., and that it was not proposed to continue the experiment.

Another matter which it is very difficult to determine by borings is what effect the pressure of the ground may have on the works which it is proposed to construct or what safe foundation pressures can be adopted. We have recently had an important discussion in this Institution on earth pressure, and suggestions were made, after some experiments had been carried out, that the old formulæ for earth pressure might with advantage be revised. The experiments referred to were not on a large enough scale to enable any definite conclusion to be arrived at, but discussion showed that there were different views on the best method of calculating the pressure of a soft material of a more or less uniform character. When there are real differences of opinion on theory, and when there may be considerable local variation in the character of the material to be dealt with, it is easy to imagine the difficulty of accurate appreciation of the strength required for underground works, when the only data afforded by borings arrive in a crushed-up state through a comparatively small tube Long experience in such cases is the principal base to work from, but even then considerable latitude is left to the personal factor or even to the imagination of the engineer.

There have been cases where borings have been very carelessly and inaccurately made and wrongly described, and there is nothing which brings more trouble in its train. I have in mind borings for a very important work, made by the client and supplied to the engineer, where the information supposed to come from the borings proved to be partly of an imaginative character. Fortunately such cases are of rare occurrence, as engineers generally have borings made under their own control, and recognise the necessity of having a thoroughly reliable assistant continually in charge of the work.

In some cases there are such great difficulties in putting down borings that hope of information from this course must be abandoned. We can sometimes get help by putting them down outside the site, and geologists, who have studied the district, can give great assistance. We cannot, however, be certain. It was mentioned in the paper read here on the Assouan Dam that it was not possible to obtain borings where the line of the dam crossed the three summer channels of the Nile, on the edge of the First Cataract, owing to the rush of water. It was assumed that in the bed of these channels, which were very deep, all the soft granite had been eroded and that the river was flowing on solid rock. This view seemed reasonable, particularly when it was known that the sides of the channels, as far as they could be examined, were good granite. When the channels were closed off one by one, by temporary dams, it was, however, found that there were very great depths of decomposed granite at the bottom of the channels. The cost of the additional excavation and masonry was very great, but fortunately, owing to an exceptionally low and late Nile flood, the time of completion of the work was not delayed.

Another case I might mention where borings were not possible was that portion of the Rotherhithe Tunnel under the River Thames. The line of tunnel passed in front of the entrance to the London Docks on one side and the Surrey Commercial Docks on the other side of the river, and owing to the shipping entering and leaving the docks it was not possible to make borings. The only information as regards strata in the river length given to those tendering for the work was that obtained by dredging some comparatively shallow holes in the river bed near the line of the work. There is considerable variation in the bed of the Thames, even in comparatively short distances, and the contractor, as a preliminary operation, very wisely drove a small pilot tunnel near the top of the large tunnel right across the river so as to obtain information, and incidentally it was also useful for other purposes.

In both cases, which are not isolated instances, and are only mentioned as they come within my own knowledge, the estimates of cost and time had to be made on imperfect information, but the best which could be obtained.

I might dilate at much greater length over the pitfalls open to engineers in connection with the want of knowledge of what is below the surface of the earth. I might, for instance, take up some of your time in considering mining or oil enterprises. The details of such works are, however, beyond my personal knowledge, but those who are connected with them know well how often disappointments occur. I have, however, probably dealt sufficiently with this point to show how far removed from an exact science are those works which have, in whole or in part, to be carried out below ground level.

There are other causes which prevent engineers from obtaining exact results, and the war of the elements is very real to them. Many an engineer who has been carrying out harbour works stands helpless and dismayed on his works when an exceptionally heavy storm comes at a specially critical stage of construction, and when the work of months may have vanished in a few hours. It is no consolation to him to know that the contractor standing beside him may have to bear the money loss occasioned by such damage, and it may be less consolation if he knows that on returning from their gloomy inspection he and the contractor will be closely examining in different offices the liability clauses of the contract to make sure of their exact meaning.

Such a picture, to a greater or less degree, is not uncommon on works of this class, as it is quite evident one cannot anticipate their construction without the occurrence of heavy gales, and cannot expect unfinished work to be in a condition to meet such storms without damage. It is unnecessary to refer to damage of the same cause to floating plant, the loss of which is generally a very serious matter.

It is not, however, only unfinished works which suffer. We can probably all bring to mind finished works of the same class which have stood for years and have eventually been overcome by storms of exceptional fury. In some cases failures of such completed works are not due to any initial mistake in design, but are owing to the fact that the inevitable ravages of storms for many years have not been dealt with as they occur, and that in fact maintenance works have been conspicuous by their absence.

Of course, harbour works are not the only ones which have to lament the occurrence of exceptional storms during construction. They often cause considerable damage to incompleted steel work, such as bridges and roofs, and in fact they take their toll from time to time from all works.

The effect of heavy and continuous rain has been brought

before us not so long ago by the great damage done in Paris and other places along the Seine. Nearer home, there are very few years when engineers and others have not to lament destruction by floods on a smaller scale in the Thames Valley and other places, a subject which was referred to by Mr. Ross in his address last year. It is in tropical countries, however, that the greatest havoc is caused by rain. I have recently come across great damage to railways in the tropics and extraordinary and destructive floodings in the neighbourhood of Colombo.

Even in countries like Upper Egypt, which are supposed to be, and practically are rainless, I have seen very long lengths of railway banks completely washed away by one of those rainstorms, which are very few and far between.

In some countries where exceptional cold is experienced, the after effects of continuous frosts have to be fully allowed for in engineering works, both in estimates in cost and time. When I was engaged on the construction of a dock in Canada, many years ago, great efforts were made in the early winter to get the dock walls up to such a level as would prevent them being covered by the material from the slopes at the back of the walls, which was sure to come away in the spring. Although it was thought we had been successful in raising the walls to the necessary height, it was not until June in the following summer that we succeeded in clearing away all the material which covered them. Extremes of temperature also often caused considerable difficulty as regards expansion and contraction in engineering works, and I have on more than one occasion experienced some unpleasant results therefrom.

There are other matters affecting not only the estimates of cost and time, but also the utility of engineering works, which are due to the impossibility of being able to arrive at exact conclusions on many points which arise. In the case, for instance, of a harbour constructed on an open coast, where it is often necessary to enclose a large area of the sea, there are many questions the solution of which can only be dealt with as the work proceeds. It may be quite possible definitely to design the character of the works enclosing the harbour, to calculate roughly the velocity of the tidal water entering or leaving the harbour through an opening or openings of certain widths; but in many cases it is extremely difficult to judge what currents will be set up outside the harbour by the intrusion into the sea of such works, or the amount of deposit which may be expected in the harbour. A careful survey of the coast and sea bed for a considerable distance on each side of the proposed works, a study of all existing currents and tidal effects in the locality, the collection of information from pilots and others who are accustomed to the navigation of the coast, the investigation of what has happened in any adjacent harbour, or one situated in a similar position are all of great help. After all this has been done, there are, however, very few engineers who, when there is a considerable range of tide, would care to state the character or velocity of new currents which may be formed near the entrances, or the amount of deposit which may take place in the harbour.

Naturally, it is advisable to keep openings as small as possible consistent with safe and easy navigation, so as to reduce wave disturbance in the harbour, and an engineer, therefore, will probably not fix the width of openings, nor the exact position of the entrance works until information about currents has developed as the work proceeds.

Again, in harbour works on some coasts where sandbanks vary from time to time, few engineers find that works can be carried out exactly as originally designed. It is nearly always found that as the works proceed very considerable variations occur in the positions of shoals and channels, which necessitate modification in design.

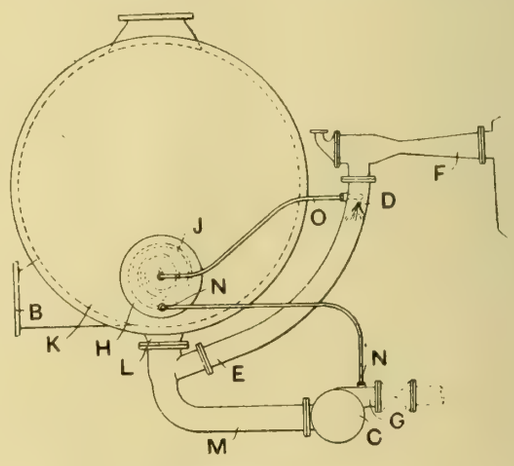
There is, again, the perennial question of the actual stresses occurring in masonry dams. Some time ago this question was fully debated before the Institution, and many experiments in connection therewith on many materials, except masonry and concrete, have been made. We still, however, know very little more than that certain dams designed on certain definite lines have been successful and that others have failed.

We may again, consider the question of the improvement of rivers, and the many intricate questions which arise in connection therewith. As one of the members of this Institution has very wisely stated, it is necessary for one to live for years with a river before all its idiosyncrasies can be mastered. It is, no doubt, comparatively easy to come to a conclusion on some matters which may obviously require to be dealt with, but dealing with an important river as a whole on a large scale probably requires more experience, study, and careful survey of all the natural features than any other work which an engineer has to deal with.

(To be continued.)

CONDENSING APPARATUS.

THE accompanying illustration shows diagramatically an arrangement of steam condensing plant, the invention of Messrs. Hick, Hargreaves, & Co., Ltd., Soho Ironworks, Bolton, and Mr. James Gunn, of the type in which the condenser is provided with a common outlet for the water of condensation and the air and vapour, and from which common outlet the air and vapour are withdrawn by an ejector or its equivalent, and the water of condensation is withdrawn separately by a water pump, the main object of the arrangement being to provide improved means for ensuring a sufficient supply of cooled water of condensation for condensing the vapour and cooling the air. In the arrangement illustrated a water cooling device J is attached to the inner side of the inspection door H of the condenser so as to lie in the water chamber of the latter, at or near the inlet B of the circulating water, and one end thereof is connected with the delivery side G of a water extraction pump C by means of a pipe N, and its other end by means of a pipe O with a spraying device D



CONDENSING APPARATUS.

which is fixed in the upper end of an upwardly ascending suction pipe E through which the air and vapour pass to the primary steam or water ejector F. By this arrangement the injection water is caused to be cooled prior to its being fed to the spraying device, as well as the ascending current of air and vapour passing through the pipe E, and a large withdrawal of air is secured by means of a primary ejector F, the injection water from the spraying device being thus supplied as a column of cold water which flows back to the suction side of the water extraction pump C in the opposite direction to the ascending flow of vapour and air. The cooling device J is of tubular form, the tube being coiled or otherwise arranged, and by attaching it to the inspection door H provided on the end cover K of the condenser in such a manner as to project into the water space the maximum effect of cooling from the inflowing column of water to the condenser is obtained, while at the same time it is accessible for rapid inspection and cleaning. It will be seen from the illustration that the water of condensation together with the vapour and air is drawn from the condenser through the same common opening or discharge branch L, and that the branch E is provided thereon leading upwardly to the primary ejector F actuated by water or steam for the withdrawal of vapour and air and a pipe connection M leading to the pump C for the withdrawal of the water of condensation.

EFFICIENCY OF PROPULSIVE MACHINERY AND LATE DEVELOPMENTS IN NAVAL ENGINEERING.*

BY LIEUT.-COMMANDER H. C. DINGER, U.S.N.

IN January, 1912, Capt. C. W. Dyson presented a paper before the Engineers' Club of Philadelphia, entitled "Propulsive Machinery and Oil Fuel in the U.S. Navy," which was followed later in the same year with a paper entitled "Engineering Progress in the U.S. Navy," read by the then Engineer-in-Chief, Rear-Admiral H. I. Cone, before the American Society of Naval Architects and Marine Engineers at their annual meeting in New York City. The first of these papers contained a comparison of the performances of the reciprocating-engined vessel "Delaware" and the Curtis turbine-engined vessel "North Dakota," while the second paper contained a comparison of the performance of the "Delaware" and the Parsons turbine-engined vessel "Utah." In both of these comparisons the decided superiority in economy of the reciprocating engine over the turbine for battle-ship propulsion was fully demonstrated.

That this apparent superiority was due to faulty practice in the design of propellers in the case of the Parsons turbine, and to both turbines and propellers in the case of the Curtis turbine, has been demonstrated by the trials of later vessels, in which the turbine revolutions have been very considerably reduced; and in the cases of Curtis turbines the turbine design has been radically changed in quite a number of particulars. In the cases of the latest two turbine-engined vessels, the economy has been still further improved by fitting cruising turbines driving the main shafting through mechanical reduction gear.

TABLE II.—*Machinery Characteristics of Reciprocating-engined Vessels.*

	"Delaware."		"New York."		"Oklahoma."	
Engines—						
Type	Vertical, inverted, 4-cylinder, triple-expansion					
Number	2		2		2	
Cylinder diameter, in.—						
High pressure	38·5		39		34·98	
Medium pressure	57		63		59·0	
Low pressure	(2) 76		(2) 83		(2) 78·0	
Stroke, inches	48		48		48	
Clearances (total per cent.)	Top	Bottom	Top	Bottom	Top	Bottom
High-pressure cylinder (H.P.)	15·57	16·77	14·29	13·54	7·226	9·586
Medium-pressure cylinder (M.P.)	12·71	14·43	12·18	14·85	9·284	12·499
Low-pressure cylinder (L.P.)	11·91	13·04	13·75	16·30	8·900	12·400
Ratio—						
H.P. : M.P.	2·22		2·61		2·890	
M.P. : L.P.	3·58		3·47		3·508	
H.P. : L.P.	7·92		9·06		10·130	
Valves—						
Type	Piston with short, straight ports.					
Number	1 H.P., 2 M.P., 4 L.P.		1 H.P., 2 M.P., 4 L.P.		1 H.P., 2 M.P., 4 L.P.	

Since the trials of the "Delaware," "North Dakota," "Utah," and her sister ship "Florida," the following vessels have been completed and tried and commissioned: "Arkansas," "Wyoming," "New York," "Texas," "Oklahoma," "Nevada," and "Pennsylvania." Of these vessels the "Arkansas" and "Wyoming" are sister ships, and are fitted with Parsons turbines on four shafts. The "New York" and "Texas" are alike and have reciprocating engines on two shafts. The "Oklahoma" and "Nevada" are also sister ships, the first having reciprocating engines while the other has Curtis turbines with cruising turbines and reduction gear. Both vessels have two shafts. The latest vessel, the "Pennsylvania," is also fitted with Curtis turbines and with cruising turbines and reduction gear, but the power is divided among four shafts.

In tracing the advance in economy in turbine propulsion, that vessel of each pair of sister ships showing the better trial performance will be considered in order to eliminate favouritism of one type over the other, and with this object in view the following vessels will be used in the argument: (1) Reciprocating-engined vessels "Delaware," "New York," "Oklahoma." (2) Parsons-turbine-engined vessels "Utah," "Arkansas." (3) Curtis-turbine-engined vessels "North Dakota," "Nevada," "Pennsylvania."

In order to furnish a proper understanding of the conditions of operation of the machinery, the characteristics of the vessels' hulls, their machinery, and their propellers must be at hand for reference, and these characteristics are given in Tables I. to III. The following is a detailed description of the turbines of the "Nevada" and "Pennsylvania":—

U.S.S. "Nevada" Turbine Data.—The high-pressure turbine has five wheels and two drums, the 5th-stage wheel being secured to the forward drum, the steam being divided after leaving the wheel stages. The wheels are separated from each other by diaphragms containing the steam nozzles. There is one stage on each wheel with two rows of buckets each, except the 1st-stage wheel which has four rows, all having a pitch diameter of 132in. The forward drum, 6th to 14th stages, inclusive, has nine rows of buckets with a pitch diameter of 119in., and the after drum, 15th to 30th stages inclusive, has 16 rows of buckets with a pitch diameter of 118⅝in. The low-pressure turbine has one drum of 38 stages and 38 rows of buckets for ahead conditions, and one wheel and one drum for backing. The backing wheel, one stage, has four rows of buckets with a pitch diameter of 137·55in., and the drum, nine stages, has 11 rows of buckets with a pitch dia-

TABLE I.—*Hull Characteristics of Vessels.*

	Delaware.	North Dakota.	Utah.	Arkansas.	New York.	Oklahoma.	Nevada.	Pennsylvania.
Length on load water line	510ft. 0in.	510ft. 2¼in.	510ft. 0in.	554ft. 0in.	565ft. 0in.	575ft. 0in.	575ft. 0in.	600ft. 0in.
Beam	85ft. 2⅝in.	85ft. 2¼in.	88ft. 2⅛in.	93ft. 2⅝in.	95ft. 2⅜in.	95ft. 2⅜in.	95ft. 2⅜in.	97ft. ¼in.
Draught on trial	27ft. 2in.	26ft. 11⅜in.	27ft. 10⅞in.	27ft. 11 3/16in.	27ft. 9¼in.	28ft. 6in.	28ft. 3 1/16in.	28ft. 9¾in.
Displacement on trial, tons	20,209	20,051	21,268	25,496	26,300	27,500	27,222	31,400
Coefficient of fineness, block	0·6000	0·6000	0·5837	0·6220	0·6100	0·6170	0·6080	0·6460
Coefficient of fineness, mid-section	0·9798	0·9810	0·9792	0·9850	0·9900	0·9840	0·9820	0·9820

TABLE III.—*Machinery Characteristics of Turbine-engined Vessels.*

	"Arkansas," "Utah" and "Florida"	"North Dakota."	"Nevada."	"Pennsylvania."
Type of turbines	Parsons reaction.	Curtis, wheel stages only.	Curtis, wheels and drums.	Curtis, wheels and drums.
Number of shafts	4	2	2	4
Rotor diameters, inches*—				
High-pressure	71	144	132–138⅞	132–120
Low-pressure	97	—	120	138
High-pressure cruising	71	—	38–41	30
Intermediate-pressure cruising	70	—	—	—
Low-pressure cruising	—	—	—	30
High-pressure astern	71	—	137·55	84–108
Number of stages—				
High-pressure	6 (91 rows)	9	5 wheel, 25 drum	4 wheel stages 39 rows on drums.
Low-pressure	6 (39 rows)	—	38	55 rows on drums.
Revolutions per minute	320	280	212	210
Steam pressure, pounds per square inch	200	250	250	250

* All pitch diameters except in second column.

* Paper presented at a meeting of the Philadelphia section of the American Society of Mechanical Engineers, May 23rd, 1916.

meter of 120in. The backing wheel and drum are separated by a diaphragm containing steam nozzles.

"*Pennsylvania*" *Turbine Data.* The high-pressure ahead turbine has three wheels and two drums, the 3rd-stage wheel being secured to the forward drum. The wheels are separated from each other by diaphragms containing the steam nozzles. There is one stage on each wheel, with three rows of buckets (132in. P.D.), except the 1st-stage wheel which has four rows of buckets. The forward drum has 18 rows of buckets and the after drum 21 rows of buckets (both 120in. P.D.). The low-pressure ahead and astern turbine has two drums. The forward drum has 12 rows of buckets for ahead conditions (138in. P.D.),

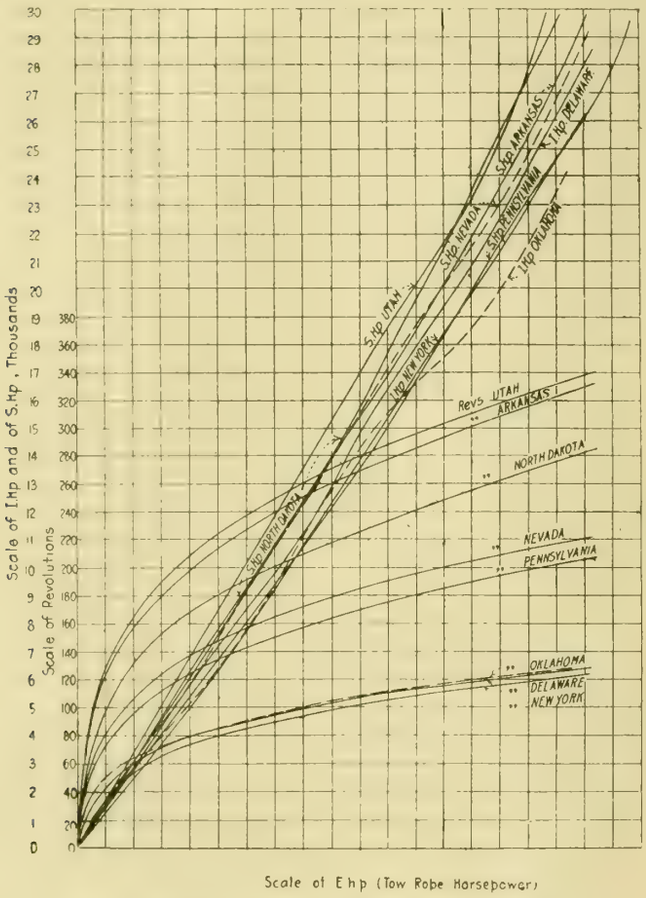


FIG. 1.—COMPARATIVE PERFORMANCES OF NAVAL VESSELS.

and the after drum 13 rows of buckets for astern conditions (120in P.D.). The high-pressure astern turbine has three wheels and one drum: each wheel has three rows of buckets except the first stage, which has five rows (108in. P.D.). The drum has 17 rows of buckets (84in. P.D.). The high-pressure cruising turbine has four wheels, two rows of buckets on each, except the first has three (30in. P.D.). The low-pressure cruising turbine has six wheels, two rows of buckets on each (30in. P.D.).

The cruising turbines for the "Nevada" were designed to give requisite power to pass steam through them up to a speed of 15 knots. Those for the "Pennsylvania" were designed to pass steam through them up to a speed of 12 knots. They were, however, used up to 15 knots by making use of special by-passes. In both vessels the cruising turbines may be used at higher speeds than those originally designed by keeping the cruising turbines in operation and at the same time admitting some live steam into the main high-pressure turbines.

Comparison of Economical Performances.—The curves in Figs. 1 and 2 have been plotted in order to establish a definite basis of comparison of the economical performances of the different vessels, and it is believed that the comparison thus made is very easily comprehended. The curves are plotted from the trial-trip data of the various vessels, which are believed to be reliable, but which cannot be taken with the refinement of a laboratory experiment.

Construction of Curves. Fig. 1, lower part, gives the effective horse-power and revolution curve for each of the several vessels. Fig. 1, upper part, gives the effective horse-power and indicated or shaft horse-power curves for each of the several vessels. As plotted they are really curves of relative propeller efficiency, and the closer the curve comes to the horizontal the greater the propeller efficiency. The curves indicate graphically the general improvement in propeller design made in succeeding vessels. It will be seen that curves of the two latest vessels, the "Oklahoma" and "Pennsylvania," run fairly close together up to an effective horse-power of 12,000, though one is a turbined vessel running at 181 revs. per min. and the other a reciprocating-engined vessel running at 118 revs. per min.; but above this point the reciprocating engine propellers are decidedly superior.

Fig. 2 gives the effective horse-power and B.T.U. utilised, obtained by plotting the value of $W\ H \div (E.H.P.)$ where W = total water consumption per hour at point where the effective horse-power (E.H.P.) mentioned is used, and H = total heat of 1lb. of steam at boiler less feed temperature. These curves therefore give a comparison of combined engine and propeller efficiency, eliminating the boilers. Similar curves might be plotted showing the engine efficiency only. But as the type of machinery affects the propeller efficiency, it is a better comparison to have the combined efficiency of engines and propellers.

In plotting these curves where saturated steam is used the steam is assumed to be dry. Where superheated steam is used the temperature of steam recorded is employed. It is believed that the curves are truly comparable graphs of the economical efficiency of the machinery of the different vessels, and are unique in this particular, since they take into account propulsive work performed per heat unit supplied in the steam to the engine. They also take into account water for all purposes, except for the "North Dakota" the water for dynamos is excluded. Any other vessels for which the water consumption, steam pressure, feed temperature, shaft horse-power, and effective horse-power are known, can be compared in the same way and the relative efficiency of the machinery shown.

The disclosures from the curves of the B.T.U. per effective horse-power are extremely interesting. The "New York" here shows the best performance, and this represents the combination of efficient propellers, good reciprocating engines, and the use of a moderate degree of superheat. In comparing the "Delaware," "New York," and "Oklahoma," we find their propeller efficiencies stand in the following order: (1) "Oklahoma," (2) "New York," (3) "Delaware." The order of their economical efficiencies is: (1) "New York," (2) "Delaware," (3) "Oklahoma." Both the "New York" and "Delaware" have superheat; the "Oklahoma" has none. The relative standing of the

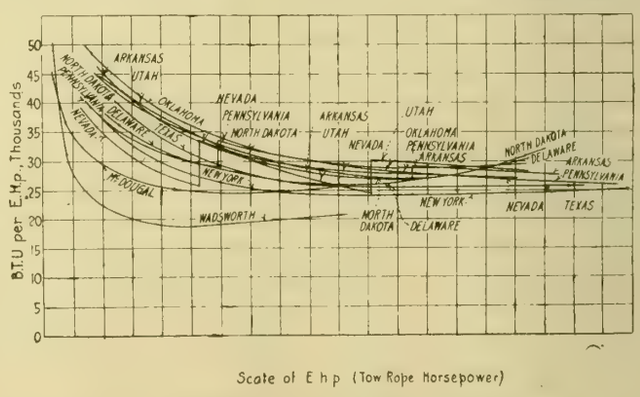


FIG. 2.—COMPARATIVE PERFORMANCES OF NAVAL VESSELS.

"New York" and "Delaware" is largely accounted for by the difference in propeller efficiency. The "Oklahoma" has better propeller efficiency and fully as good, if not better, engines, hence one is easily led to the conclusion that the falling off in the economical efficiency of the "Oklahoma" is due to the non-use of superheat. Similarly, the performance of the "Nevada" and of the "Pennsylvania" could have been improved nearly 10 per cent. by using superheat.

The "Nevada" and the "Pennsylvania" are fitted with geared cruising turbines. The superior economy secured by these over other turbine vessels is clearly shown by the curves. The curves also indicate that the Parsons vessels at high speeds give about the same economical result as the Curtis-turbined "Nevada" and "Pennsylvania." The propeller efficiencies of the "Nevada" and "Arkansas" are about the same. However,

within the range of the intermediate-pressure cruising turbine the Parsons vessels are superior, while at very low speeds the economy in the turbine vessels is about the same. The "Pennsylvania" at high power shows slightly better economy than the "Nevada," this being expected since it is a later and somewhat better design, and better propeller conditions due to the use of four screws running at same revolutions are obtained. At low power the "Nevada" gives better economy results. The curves of the "Utah," "Arkansas," "Nevada," and "Pennsylvania" are really a series of curves, as they jump from one combination of turbines to another.

In plotting the curves, that for each condition is laid down and carried up to the point where the next combination of turbines comes in. Actually, by means of by-passing steam, the results will not follow the separate lines; but, as the limit of one combination is reached, by-passing is resorted to and a better result secured than if a complete shift to the next combination were made.

As far as economy at the different speeds is concerned, there is not much choice between the different types of machinery when they have proper propeller efficiency. At very low powers the reciprocating engine is about as economical as the geared cruising turbine, both of these being more economical than directly connected cruising turbines. The use of superheat would improve the performance, however, especially that of the reciprocating engine and impulse turbine.

The foregoing indicates that when all advantages of design are used, about the same economical results are secured with either reciprocating engines, Parsons turbines, or Curtis turbines, and that other matters besides mere economical performances should decide the choice of prime mover as between the several types. It also goes to show that when the losses are properly guarded against it is the range of temperature that really counts in securing efficient propulsive machinery. Therefore, the most effective measures that can be applied are those which increase the range of temperature that can be used and those which conserve the use of the heat units supplied. Hence we have reasons for use of superheat, the employment of the highest possible vacuum practicable, the best possible use of feed-heating apparatus, and economical operation of auxiliaries.

The curves of the destroyers "McDougal" and "Wadsworth" have also been plotted (Fig. 2). Owing to large differences in hulls and speeds, the destroyers are not directly comparable with the battle-ships, but they are comparable with each other, and the curves indicate the general efficiency of the propulsive machinery of representative destroyers, and strikingly show the economical advantage secured by use of gearing.

(To be continued.)

THERMAL REACTIONS OF CAST IRON.*

BY PROF. THOMAS TURNER.

ADOPTING the time-honoured language of Lord Macaulay, it may be assumed that "every school boy knows" that substances when heated expand, and with every increment of temperature there is a corresponding increase of volume. Conversely, when any material is cooled there is a corresponding diminution of volume, the amount of such contraction per unit of temperature depending upon the inherent properties of the material. But though it is true that over a short range of temperature the change of volume is strictly proportional to the change of temperature, it is not strictly true over wide ranges of temperature. Solids, for example, have a higher rate of expansion when near their melting points than at lower temperatures. Further, in very many instances, accurate observations show that there are distinct irregularities, and that these are indications of important physical, allotropic, or chemical changes which occur at certain definite temperatures. It is noteworthy that two of the most important substances with which we have to do, namely, water and cast iron, show remarkable interruptions in their rate of contraction when cooling—in fact actual and marked expansion takes place. The profound and beneficial influences which result in the climatic conditions of our globe, from the expansion of water when changing to ice, are well known to all geographers. The inconveniences which accompany such advantages are known to the householder and the engineer. The expansion of cast iron during, and shortly after, solidification has the great advantage of rendering the metal specially suitable for giving a perfect reproduction of the desired pattern. But this advantage is accompanied by troubles which beset the foundryman, and which often lead to the production of castings that are warped or bent, or which spontaneously crack after being allowed to cool.

In comparing water with cast iron, a marked difference in constitution is observed. To the chemist water is a compound, composed of oxygen and hydrogen, yet physically it is all one thing; one "component" or one "individual." So long as it is liquid it is one "phase." When water passes into ice we have another phase, while water vapour is a third phase. With the gaseous phase we are not interested at present, and it introduces the further variant of pressure. Considering only the liquid and solid phases, if these be mixed together in any proportion and kept at exactly 0° C., no change will occur in the weight of ice or of water. But if the temperature be raised and sufficient time given, the whole of the ice will melt; if the temperature be lowered, and sufficient time given, the whole of the water will freeze. Hence there is only one temperature at which the two phases can remain in equilibrium. With a falling temperature, no matter how many phases may be present, only one phase can separate at one time.

Cast iron is not an element, or a compound, or a solution, but a heterogeneous mixture, including a number of "individuals" or "components." The elements which are always present are carbon, silicon, sulphur, phosphorus, and manganese. Variable small quantities of other elements are also to be detected. The actual substances in cast iron include iron (or ferrite), carbon, iron carbide (Fe_3C), iron silicide (Fe_2Si), iron sulphide (FeS), iron phosphide (Fe_3P), and manganese sulphide (MnS). There are mixtures of the foregoing, yielding eutectics, such as the iron carbide eutectic with 4·3

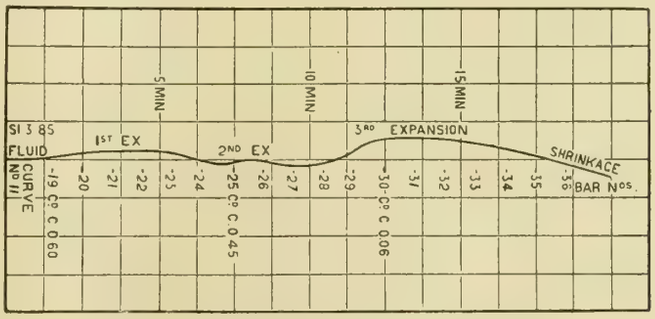


FIG. 1.—CURVE SHOWING RESULTS OF KEEP'S TESTS.

per cent. of carbon, the iron-carbon-phosphorus eutectic with 2 per cent. carbon and 6·7 phosphorus. There is also pearlite with 0·9 per cent. carbon. There are also solid solutions, such as silico-ferrite which has the same crystalline habit, or is isomorphous with iron. It therefore is not enough merely to know the ultimate chemical composition of our cast iron. We must know in what form the elements are present, and how they are arranged. Having so complex a structure and composition in the solid cast iron, the question naturally arises—Do these substances exist in the separate state from the beginning, or is there a definite and sequence of formation? A generation ago no satisfactory answer could have been given to such an enquiry. The use of the microscope and the pyrometer, and the application of the "phase rule," have done much to make clear what really occurs. When cast iron commences to solidify, the carbon, silicon, phosphorus, and other elements are in a state of solution. Any separation which occurs takes place afterwards as the metal cools. It takes place in definite order and at definite temperatures. So long as the temperature is falling, and sufficient time is given for equilibrium to be attained, only one phase can separate out at a time. If there is a fixed temperature at any point during the process of cooling, then two substances may separate out together and yield a eutectic. In no case can more than two phases separate out together. It has been found that the condition stated is true only so long as sufficient time is given for equilibrium to be attained. In a large casting, which is cooled very slowly, we approximate to equilibrium conditions. But in many cases the cooling is so rapid that one separation is not

* Paper read before the Cleveland meeting of the American Foundrymen's Association.

completed before the temperature is reached at which another begins. We have thus an overlapping or lag, and with extremely rapid cooling changes may be altogether suppressed. In such cases heat which would otherwise have been evolved is retained in the solid, and the result is called metastable. Metastable solids are often hard and brittle, like glass, or white cast iron. By annealing at a proper temperature, the heat which has been retained internally is allowed to change its form, and to be liberated; the condition of equilibrium is attained, and the solid becomes relatively soft.

Returning now to the subject of expansion in cast iron, it may be noted that practical men were convinced that expansions occurred long before there were any scientific observations to support that view. These preliminary observations did not carry us beyond the point at which the metal became solid in the mould. Nor was attention given to the influence exerted by the various elements which are present, in widely different proportions, in different samples of grey cast iron. Really accurate and useful knowledge on this branch of the subject may be said to commence with the work of W. J. Keep, of Detroit, who introduced an apparatus for automatically recording the changes of length in a sand-cast bar from the moment it begins to solidify until it is cold in the mould. By modifications of this method, and with the addition of temperature measurements, the question has been since more fully investigated in my laboratory. The observations have not been confined to cast iron, but have been extended to brass, bronze, and other alloys.

A fundamental experiment by Mr. Keep calls for special mention. A number of similar bars were poured from the same ladle, side by side, at the same time. From one of these an autographic record of changes of length was obtained. The others were quenched, one at a time, at regular intervals during cooling. The quenched bars were afterwards analysed. The results are represented in Fig. 1. The metal was a grey phosphoric cast iron, containing 3·85 per cent. silicon. It showed three distinct expansions, which reached their respective maxima at about 4 min., 8 min., and 14 min. after casting. It was not until about 20 min. after pouring that regular contraction commenced. The combined carbon had fallen during these expansions from 0·60 to 0·06 per cent. in the chilled bars. Mr. Keep's work was of importance not only because it showed the nature and sequence of the expansions which take place, but also on account of its suggestiveness for further enquiry.

The questions which naturally arose were those of dealing with the cause or causes of the expansions, the thermal changes which occurred, and the changes in structure and properties which resulted therefrom. In the investigations which ensued I was fortunate in having the assistance of Dr. O. F. Hudson. Among the facts ascertained were the following: (1) That most metals and a number of alloys give a regular contraction in the cast bar; (2) that with white cast iron, free from phosphorus, there is only one small expansion, and one temperature arrest, which occurs at about 670° C.; (3) that with grey cast iron, free from phosphorus, there are two well-marked expansions, and two distinct temperature arrests, which occur at about 1·135° and 695° C., respectively; (4) that with increase of silicon these arrest points occur at higher temperatures, and nearer together. In other words, though both are raised, the lower, or pearlite point, is raised more than the upper, or iron carbide eutectic point; (5) that the addition of a small quantity of manganese, together with silicon, diminishes the rise in the pearlite point, and leads to a more complete decomposition of the pearlite carbide, in other words to the production of fine-grained graphite from the combined carbon; (6) that in grey irons containing phosphorus there is an additional or third arrest, which occurs at a temperature between those given, or at about 900° C. A typical expansion curve and the corresponding temperature curve for grey phosphoric iron is given in Fig. 2.

There are doubtless other volume changes besides those that have been mentioned. These include what occurs when silicon dissolves in iron to yield the solid solution known as silico-ferrite. The separation of manganese sulphide, and iron sulphide, during the cooling of cast iron, doubtless also produces volume changes, though such changes are believed to be relatively unimportant. The most important of the conclusions which were derived from the experiments conducted at the University of Birmingham have since been confirmed by other investigations, employing various forms of apparatus. Special mention should be made of the careful work of Prof. Wust, of Aachen, and the practical applications by Messerschmitt. More recently Mr. Heggie, of Birmingham, who is a foundry manager of considerable experience, has conducted a number of tests. The object was to ascertain whether in actual practice, with varying thicknesses of castings, the expansions followed in the same order as in my earlier experiments. The tests were made with a rectangular casting of special pattern. It was a frame, made with thin ends, and with one side much thicker than the other. It was cast in sand in the ordinary way, but arrangements were made for recording the changes of length of the two sides during cooling. It was found, as might be anticipated, that the expansions in the thin bar were similar to and occurred in the same order as in the thick bar. But since the thin bar cooled more rapidly, its second expansion occurred while the thick bar was contracting after its first expansion. Hence while one side of the frame was expanding the other was contracting, and internal strains were set up in the casting. Positive and negative effects followed, until at length the thin side was uniformly contracting, after its third expansion, while the thick side was markedly expanding at about 700°. As the metal is quite

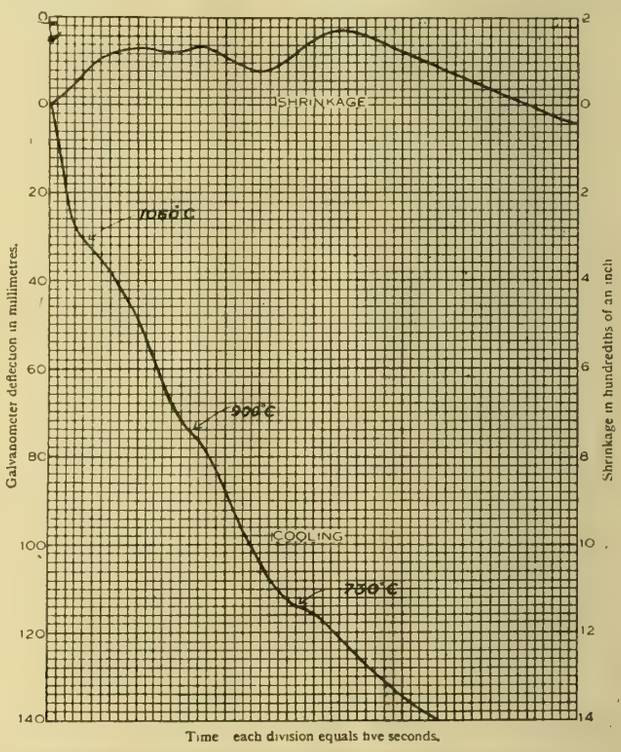


FIG. 2. EXPANSION AND TEMPERATURE CURVES FOR GREY PHOSPHORIC IRON.

solid at such temperatures, the importance of the strains which are thus set up will be readily appreciated.

The arrests in the rate of cooling of a hot body are obviously due to evolutions of heat at a given temperature or temperatures. These evolutions during cooling are merely the converse of heat absorptions during heating. A body which cools down in this irregular manner does not heat up uniformly. In practice it is much more easy to detect arrests during the cooling of a casting than while heating up in the cupola. But there can be no doubt that the one is the converse of the other. If cast iron is chilled and the transformations are suppressed, heat is stored up in the solid. Hence it would save fuel in remelting if the iron were chilled as it comes from the furnace, instead of being cast in sand in the usual manner. The absence of sand on the surface is another incidental advantage. On the other hand the ironfounder cannot judge of the character of the iron by fracture if it has been so chilled. It is also held, though I know not upon what scientific evidence, that metal which has been chilled retains some of its acquired hardness when remelted. It would scarcely be anticipated that such a result would follow, but it would be rash to contradict the opinion of a practical man without the support of a series of very carefully conducted tests.

An evolution of heat which causes an arrest in the rate of cooling may be due to a change in state, as when a liquid is converted to a solid, and parts with its latent heat of fusion. It may arise from an allotropic or polymorphic change, such as those which occur in pure iron, in iron sulphide, and many other substances. Thirdly, it may be due to the splitting up of a combination, the formation of which necessitated the absorption of heat. To this last class most of the changes which occur in cast iron belong.

With carbon iron unites to form carbides which are definite chemical compounds. Of these Fe_3C was first isolated by Abel and is well known: Fe_2C is also accepted, while the existence of Fe_4C and FeC is also suggested. Within the range of ordinary furnace temperatures only Fe_3C need be considered. It is formed by the direct union of carbon and iron, with absorption of heat. It is more stable as the temperature rises. Hence at temperatures well above the melting point of cast iron it shows no tendency to decompose. But as the temperature falls the carbide tends to decompose into iron and carbon. Hence irons which are rich in carbon often yield graphite in the form of "kish" when allowed to remain fluid just above their melting point. When only iron and carbon are present 4·25 per cent. of carbon is retained in solution, and this solidifies as an iron, iron-carbide eutectic at about 1,130° C. If the temperature falls rapidly the carbide may not have time to decompose, and white iron results. If, however, the cast iron is kept for a lengthened period at, or above, 1,000° C., the carbide decomposes and graphite is produced. The resultant is a grey iron, which may still contain carbide equal to 0·09 per cent. of carbon. This residue may almost completely decompose, with further evolution of heat, at about 700° C. One hundred volumes of carbide, completely decomposed into iron and graphite, expand to 113 volumes. The presence of silicon lowers the solubility of carbon, hence the total carbon is lower, and the formation of graphite is facilitated. The complete decomposition of the carbide is assisted by the presence of a small quantity of manganese. These facts will explain the two temperature arrests, and the two expansions observed with non-phosphoric grey cast irons.

Iron and phosphorus unite to form several definite phosphides, but only Fe_3P will be here mentioned. The phosphide becomes more stable as the temperature rises, hence steel cannot be dephosphorised if the temperature is too high. The iron, iron-phosphide eutectic, which corresponds with the iron carbide eutectic, contains 10·2 per cent. of phosphorus and melts at 980° C. In grey cast iron this binary eutectic combines with carbon to form a ternary eutectic, containing about 2 per cent. of carbon, 6·7 per cent. of phosphorus, and 91·3 per cent. of iron. The triple eutectic solidifies at about 943° C., and is the last portion of the casting to become solid. If the iron is very grey, the triple eutectic parts with its carbon, yielding graphite and the binary eutectic. The latter exists in the form of cells of irregular shape which are easily recognised under the microscope. These facts account for the evolution of heat, and the expansion, which takes place with ordinary grey cast iron, at or somewhat above 900° C.

While the three thermal reactions, just described, are undoubtedly the most important of those which occur during the heating or cooling of cast iron, there are others which are worthy of further investigation. We have for example the formation of silico-ferrite, and of silico-graphite, which appear to be of importance but of which little is known. There are also the reactions of manganese and those of sulphur, both of which would doubtless repay further study. Though our knowledge of the subject has almost immeasurably increased during a generation, there are still untrodden fields for those who follow.

The World's Production of Petroleum.—The production of crude petroleum throughout the world last year was 426,892,673 barrels. This beats the record output of 1914 by 7 per cent. The greater part of the increase was contributed by the United States and Mexico, although Russia, Argentina, and Japan also recorded small advances. Last year's output of the six principal petroleum-producing countries was: United States, 281,104,100 barrels; Russia 68,548,062 barrels; Mexico, 32,310,508 barrels; Dutch East Indies, 12,386,808 barrels; Roumania, 12,029,913 barrels; and India (including British Borneo), 7,400,000 barrels.

HEATING AND VENTILATING PRIVATE DWELLING-HOUSES.

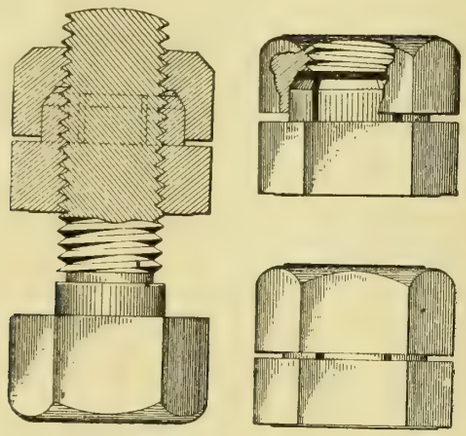
IN a paper on this subject, read before the Society of Engineers on November 6th, Mr. C. T. Alfred Hanssen, A.M.Inst.C.E., stated that in England £51,000,000 per annum was spent on heating private dwelling houses by means of open fires. Large volumes of cold air were drawn through the rooms, which were, as a rule, heated only to a few degrees above the outside air. During cold weather the results were not only uncomfortable, but were a positive danger to health, as could be proved by the great rise in the rate of mortality every time the temperature of the external air fell below 45 Fah. The present system of heating and ventilating was therefore expensive, inefficient, and unsanitary. It was commonly believed that cold air improved our health and that it enabled people to resist chills. This was perfectly true in the case of those who took active exercise in the open air, but was far from being true in the case of those who sat or stood in cold, draughty rooms, where the fresh air circulated mainly about their feet. Therefore, although vitiated air was very unsanitary, it must be maintained that cold air was still more unsanitary.

Effective ventilation did not only consist of admitting an ample volume of fresh air to our dwelling rooms, but in admitting it in such a manner that it entered at the breathing level, and that it thoroughly displaced the vitiated air throughout the whole room. This could not be done unless the incoming air had approximately the same temperature as the air in the room. If it was colder it would sink to the floor level; if it was warmer it would rise to the ceiling, and in either case it would fail to reach the lungs of the occupants. Air did not move without being acted upon by a difference of pressure due to a difference of temperature or the action of a fan or the like. The former was inadmissible for effective ventilation, therefore the latter became indispensable. In England, according to statistics for the last 64 years, there was a mild season from June to September inclusive, with an average temperature of 60·2° Fah., and a cold season from October to May with an average temperature of 44·2° Fah., when artificial heat was required for maintaining our dwelling-houses at an average of 55° Fah. To heat the volume of 22,000 cub. ft. of air per hour required for an ordinary middle-class house, in a good heating apparatus, from 44·2° Fah. to 55° Fah. required a little over a ton of coal per annum. A house could be thoroughly ventilated with warm air at a cost of about £3. 8s. per annum, taking coal at 30s. per ton and electric power at 1d. per Board of Trade unit. The heating value of ordinary town gas at 3s. per 1,000 cubic feet corresponded to that of coal at £8. 16s. 1d. per ton, and gas was, therefore, too expensive at present to be used for general heating. If, however, the price could be lowered to compete with coal, considerable domestic, sanitary, and commercial advantages would result.

Various experiments were given which showed that the present low efficiency of our heating system was due in the first instance to the incomplete combustion in an open fireplace and to the small amount of heat radiated into the room; but it was also due to the large amount of heat which escaped by conduction through the thin walls, floors, roofs, windows, and doors of our houses. Allowing for these losses, the cost of heating an ordinary middle-class house to 55° Fah. by means of open fires was prohibitive, as it required 32½ tons of coal per annum for an average winter. By means of a well-regulated economical heating apparatus this expenditure could be reduced to 8½ tons of coal per annum, and if proper steps were taken to prevent the excessive heat losses by protecting the walls, floors, ceilings, and roof with some cheap and efficient non-conductor and by using double windows, the total cost for heating the house and the incoming air might be reduced to less than three tons of coal per annum. The insulating material recommended as being cheap, a good non-conductor, proof against moisture, vermin, fire, and sound was the so-called slag-wool. One inch thickness of slag-wool would retain as much heat as an extra thickness of 12in. of brickwork.

A NEW LOCK NUT WITHOUT WASHERS.

We are indebted to the "Iron Age" for the following particulars of a lock nut in which the dead and not the moving member is locked, and which has been developed by the Western Screw and Lock Nut Co., 342, Mills Building, San Francisco, Cal. With this nut no washers are required and the nut can be locked at any point on the bolt, an arrangement which makes it possible to take care of oscillating or pulsating movements. The bolt and nut can be used over and over several times, it is explained, without damaging the threads. It is possible also to fit a United States standard nut tightly on a bolt having a V-thread, and it is also possible to make a nut tight on a loose fit bolt. The lock nut consists of two members. The lower one, which is the nut proper, is similar in form to a regular hexagon nut and has four flexible finger members projecting from its upper surface. When the upper or locking



A New Lock Nut without Washers.

member is screwed down, these fingers are compressed and the nut is frozen, as it is expressed, to the bolt. The locking action is secured by turning the locking member firmly. When locked in place this member is counted on to help carry the load. One of the features of the lower member is a number of threads which provide capacity to carry the load. The nut is released with an ordinary wrench, and when the locking member is released it will of course move as one of the ordinary type. A recent test of the holding power of one of these nuts was made by bolting two pieces of $\frac{3}{4}$in. by $1\frac{1}{2}$in. bar steel together with a $\frac{3}{4}$in. lock nut and one of the ordinary type placed 6in. apart. The steel bars were suspended on heavy springs and an air hammer delivered 500 blows per minute with a force of 25lbs. midway between the two bolts. It is stated that the ordinary nut was jarred off in a short time, thus leaving the strain on the other bolt. After nine hours of continuous jarring at this rate the lock nut was still gripping firmly.

METAL QUOTATIONS.

TUESDAY, NOVEMBER 14TH.

Aluminium ingot	—	per cwt.
,, wire, according to sizes, &c. .....from	—	,,
,, sheets ,, ,, ... ,,	—	,,
Antimony	£95/–/–	per ton.
Brass, rolled	1/4$\frac{1}{8}$	per lb.
,, tubes (brazed)	1/6$\frac{1}{4}$	,,
,, ,, (solid drawn)	1/4$\frac{1}{4}$	,,
,, ,, wire	1/3$\frac{3}{8}$	,,
Copper, Standard	£128/10/–	per ton.
Iron, Cleveland	87/6	,,
,, Scotch	—	,,
Lead, English	£32/5/–	,,
,, Foreign (soft)	£30/–/–	,,
Mica (in original cases), small	6d. to 3/–	per lb.
,, ,, ,, medium	3/6 to 6/–	,,
,, ,, ,, large	7/6 to 14/–	,,
Quicksilver	£17/12/6	per bottle.
Silver	34$\frac{3}{16}$d.	per oz.
Spelter (American)	£54/–/–	per ton.
Tin, block	£187/15/–	per ton.
Tin plates, I.C.	32/–	per box.
Zinc sheets	£75	per ton.

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1915.

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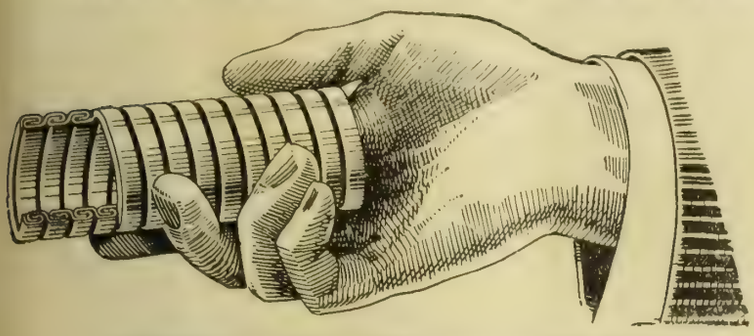

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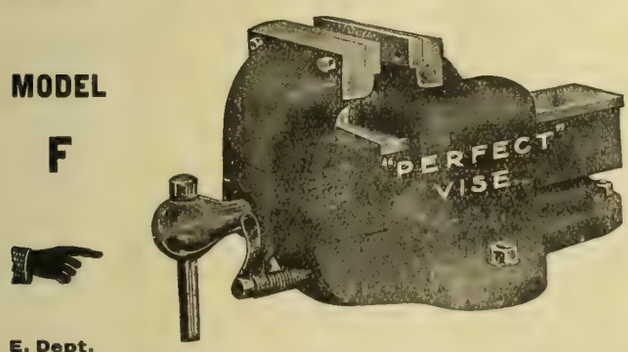

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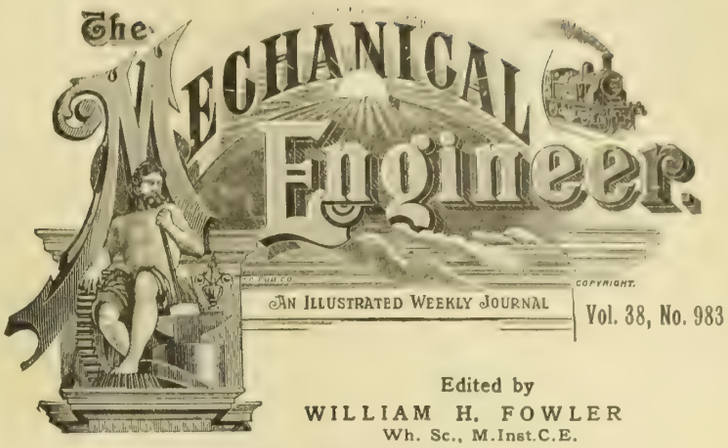

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The Metric System.

IN the chaotic upheaval of our social habits and customs and clamour for reforms after the war, it is but natural that the voice of the metric enthusiast should be heard. It is a subject on which much has already been said, and the arguments are not all on one side. At a cursory glance our system of weights and measures, with its absolute want of relationship between standards of length, capacity, and weight, seems stupid in the extreme. On the other hand, the metre and its division into hundredths and thousandths, with the cubic decimetre or litre as a standard of capacity, and the weight of a litre of water as a standard of weight, with multiplications and divisions or transformations effected by the mere shifting of a decimal point, seems simplicity itself. A closer investigation, however, of our relatively incommensurate units shows them to possess advantages in commercial dealings that the metric system of sub-division does not possess. The fact that the ton contains 20 cwts. and the sovereign 20s., that the foot contains 12in. and the shilling 12d., is a great help to mental computation in trade transactions, which does not need dilating upon. Five pounds per ton is 5s. per cwt. Six shillings a dozen means 6d each. So many shillings a foot means so many pence per inch. Again, the natural descending ratios of fractional parts of half, quarter, eighth, &c., each being half of its predecessor, seems to lend itself much better in many ways to the human mind, and is adopted even in countries where the metric system is in vogue. As regards the simplicity of the metric system, especially where conversions of dimension and weight are involved, there can be no question. Chemists long ago recognised this, and hence the metric system in chemical quantities and calculations is universal. It has required no Act of Parliament to bring this about. The system has been adopted purely on its merits, and if we were all chemists the question of metric reform

would not be a burning one. It happens, however, that the majority of the world's work, where measurement is required, is done by engineers, and it further happens that the system of screw threads, which practically decides standards in many other directions, has been worked out on the basis of the inch with its sub-divisions of half, quarter, eighth, &c., and has become woven into our workshop practice. To root this out to meet the wants of metric or decimal enthusiasts would create enormous confusion without any corresponding advantage. The matter is one that has been discussed not only here but in America, where the Government some years ago were on the point of passing an Act to make the metric system compulsory, when it was barred by the action of the engineers. The advocates of "metric reform" are, however, active in America, as they are here, and an enquiry which the Philadelphia Bourse is conducting amongst manufacturers, with a view to obtaining their opinion, has elicited a reply from Mr. Coleman Sellers, jun., the head of the well-known firm of Wm. Sellers & Co., which we take the liberty of reproducing from an American contemporary, as it sums up the pros and cons both of the metric and the British system impartially, and especially their bearing on engineering practice. The following is the extract referred to:—

"I would certainly recommend exporters to make any use of the metric system that will facilitate their foreign business, such as expressing weights and dimensions in the units used by the purchaser, if he so desires. The Bourse is to be commended for putting the necessary information before manufacturers and exporters, but I should be very sorry to see it lend itself to any propaganda designed to force the use of the metric system on the whole country by act of Congress.

"The French units have been legalised by our Government and accurate standards have been prepared for distribution. This, I think, is as far as the Government should go. I am perfectly willing that any one shall make what use of the metric system he deems desirable, but I object seriously to any attempt to force the extension of the system by legal enactment. The advocates of this course are no doubt absolutely sincere in their belief, but they approach the subject too much from a scientific point of view and do not give due consideration to the practical side. If the system is really better than ours, it will in time supplant it without the violent disturbance which would follow an enforced use.

"Our own foreign business is chiefly confined to machine tools or other machinery for working metals, and the metric system is only involved to the extent that we occasionally are required to furnish the principal screws with metric threads or to arrange a machine to cut metric threads; that is, threads in which the lead or pitch is expressed in millimetres instead of in inches or fractions of an inch. Even this requirement is not universal. We are now building machines for Russia (a metric country) which are required to cut inch threads. It really makes no difference to the buyer of a machine whether the inch or the millimetre has been the unit of measurement used in constructing it.

"As to the use of the system in our own establishment, I may say that when we began the manufacturing of the Gifford injector about 1860 we followed the drawings of the French inventor, using his units, and all our gauges and tools were made accordingly, with the single exception that the threads for the pipe connections conform to the American standard. We have continued to use the metric units in this department since it started, with entire satisfaction, but with no desire to extend it to the rest of our establishment.

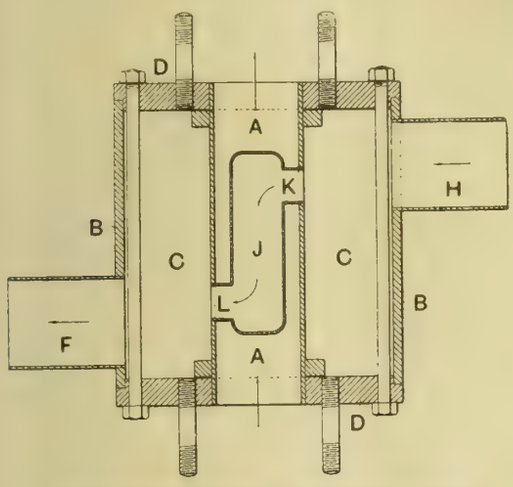
"To change a manufacturing plant such as ours from one system to the other is not so simple a matter as merely substituting a rule differently graduated, but it involves a large investment in tools and fixtures and an interference with established standards which it is practically impossible to change. This difficulty is very real, as is illustrated by the fact that even in France the metric system is not used to the entire exclusion of other standards; and in other countries, Russia for example, the English system of threads still generally prevails. The matter of thread standards is in a chaotic state in the metre-using countries, and they have not yet agreed to conform with a universal standard of diameters, pitches, and forms of thread, although numerous efforts have been made to bring this about. In fact, the subject is in the same confusion that existed in England before Sir Joseph Whitworth introduced his system of screw threads, which was suggested by the late William Sellers and officially approved by the Franklin Institute."

COAL SUPPLIES FOR POWER STATIONS.

IN his presidential address, recently delivered before the Manchester Local Section of the Institution of Electrical Engineers, Mr. A. E. McKenzie referred to the linking up of power stations, and remarked that several municipalities had already proved the great financial saving that could be effected by inter-connecting, especially in the lowering of fuel costs and the reduction in the quantity of stand-by plant necessary under such schemes. Turning to the question of fuel, the author remarked that great difficulty had been experienced by both gas and electricity supply undertakings during the past year in obtaining their necessary supplies of fuel even where it could be proved that practically the whole output was for war work. Very meagre assistance had been obtained from the Government. The Act for limiting prices at the pit had been of little real value to many, and they heard in many quarters of colliery companies evading its provisions. There was no doubt that additional legislation was required to enable electricity stations to obtain coal in sufficient quantities for their needs and at reasonable prices. The fuel procurable to-day was inferior to that obtained before the war from the same pits, because of the greater percentage of the dirt content. Indeed, a large proportion of the total fuel now offered was until recent years unsaleable. During the late coal strike more than one large electricity undertaking was only enabled to keep running by burning fuel which had been thrown on the rubbish tip in the preceding years. The present high prices of fuel had caused colliery managers to recognise more fully the very great waste that undoubtedly had taken place at many pits. As much as from 10 per cent. to 15 per cent. of the total output from some mines had in the past been left in the mines, as being too small to warrant raising to the surface. Government control should in future obviate that wastage of our great national asset. The high prices now obtaining for all classes of fuel undoubtedly called for the more efficient management of boiler-houses. The indispensability of the analytical chemists in electricity undertakings of any magnitude was not yet sufficiently recognised. Only by regular testing could one ensure getting fuel of anything approaching constant quality from most collieries, and the knowledge that such tests were made was usually sufficient to make contractors careful in sending supplies to works where that practice was followed. Nor should the chemist's efforts be confined to raw fuel tests. He should be responsible for the correct treatment of the feed water and for seeing that scale and corrosion in the boilers were prevented, and the like. The large power station of the future would, he observed, probably have a proportion of boilers gas-fired, the proportion being based upon the load factor in such manner that the extra capital incurred by the installation of by-product recovery plants would be remunerative, and the by-products of the bulk of the fuel used recovered. Gas-firing was not—could not be—a means of direct saving of fuel. The two-stage process of conversion of coal to gas and gas to steam must necessarily involve heat inefficiencies exceeding those in the direct conversion of coal to steam. Skilled analysis and extensive experience tended to show, however, that with improved producers the aggregate value of by-products recoverable from coal by conversion to gas equalled or exceeded the original coal value, and when extra capital and labour charges were taken into account the procedure led to a substantial rebate on fuel costs. There were isolated cases on record, in the days when slack could be bought at 6s. or 7s. a ton, where large boiler installations were fired throughout the year substantially for nothing, and as the value of the various by-products fluctuated largely in sympathy with coal values one might expect a net saving by the system of between 4s. and 7s. per ton of coal consumed.

VAPORISER FOR INTERNAL-COMBUSTION ENGINES.

THE accompanying sectional view shows a design of vaporiser for internal-combustion engines, the invention of Mr. R. P Robinson, 259, Branstone Road, Burton-on-Trent. Referring to the cut, A is the vaporiser chamber, which is in the form of a tube, and B is the jacket which surrounds the vaporiser tube, so as to form an annular space C between them, the jacket being fitted with end plates D, held together by bolts. Openings are provided in the end plates for the insertion of the two ends of the vaporiser tube, metal packing rings being provided for making a tight joint. The vaporiser is attached to the induction pipe and to the carburetter, respectively, by means of the studs shown. H is the inlet for the exhaust gases to the space C, and F is the outlet for the gases therefrom. J is a hollow body of tubular shape, closed at the two



VAPORISER FOR INTERNAL-COMBUSTION ENGINES.

ends, and is in communication by the connections K and L with the annular space C, so that a portion of the exhaust gases which enter the chamber flow through the hollow body before passing to the outlet F. The device operates as follows: The carburetted mixture from the carburetter is drawn into the induction pipe of the motor by the suction action of the latter through the vaporiser pipe or chamber A in the direction of the arrows, the exhaust gases at the same time flowing through the inlet pipe H into the annular chamber C, and thence through the outlet F, a portion of the gases passing through the hollow body J. It is, therefore, obvious that the carburetted mixture in its passage through the vaporising chamber A comes into contact with the hollow body which has reached a considerable temperature through the medium of the exhaust gases, so that the volatile portion of the carburetted mixture is completely vaporised before passing into the induction pipe. The vaporiser described is particularly suitable for vaporising petroleum, although it is also applicable for the vaporisation of lighter hydrocarbons.

THE PREVENTION OF CRANE ACCIDENTS.*

BY F. H. ELAM.

IN spite of the fact that engineers and manufacturers have devoted their best efforts for years to the design and construction of cranes that will efficiently and safely perform the work for which they are intended, there is still a large element of danger in the daily operation of this kind of equipment. Even the manager of a new plant, equipped with the latest type of cranes, is not relieved from troubles due to accidents, for although the equipment is perfect in every respect, there is still an opportunity for man failure. The human machines that operate and repair this up-to-date equipment are not standard and never will be. Guards will be removed during repairs and not replaced, or safety devices will not be used according to instructions, and these and other failures and omissions will cause workmen to be injured and possibly killed. The plant manager will have to call upon his resources of fortitude and patience to keep from losing faith in the efficacy of safety endeavour. As in other equipment, every movable part on a crane should be guarded. If some part that seems to be protected by its inaccessibility is left unguarded the foreman is likely at any time to have cause that will warrant his subscribing to the theory of the late Mr. Darwin when some workman proceeds to qualify, both physically and mentally, as a missing link by climbing to that particular place and satisfies his curiosity to see if the thing really moves, with results that are usually painful to himself and to his employer.

A reference would not have been made to this type of workman if it was not a fact that it is such workmen who resist all efforts to provide for their safety by refusing to follow safety instructions, by removing guards, and even destroying them. There seems to be a disposition to ignore or overlook this situation and to continually lay stress upon the duties of the employer. The employer has a duty to perform regarding safety that only he can discharge, and it is firmly believed that he is performing with far more earnestness and sincerity than the rank and file of his employés are performing and discharging their duty regarding safety for their neighbours and themselves. The employer is decidedly at a disadvantage in dealing with this situation, because the workmen are usually not recognised as being unduly careless until an accident has occurred. The damage has then been done, and it is too late to do anything except patch him up and pay the costs.

The trolley is the seat of the vitals of a crane, and should be so constructed and guarded that loose or broken parts cannot drop through, endangering the men below, and that men cannot be injured by the moving parts. The various parts of the trolley should be easy of access for repairing and cleaning.

Brake magnet plungers and counterweights seem to have an uncanny faculty of becoming unattached and falling at the exact moment that a workman is in the proper position to receive them on his head, and should, therefore, be securely fastened or guarded. Two-member hinged guards should be used wherever possible for gears, and should be securely fastened to the trolley frame. Main and auxiliary hoists should be equipped with effective limit switches, which should be kept in perfect repair. Cables should be used as the hoisting agents, and the use of the chain should be discouraged, as cable has many times the safety factor that chain has, besides being cheaper. Bridge and trolley wheels should be guarded by stirrup-type sweep guards. The use of wire brushes for this purpose should be prohibited, for the reason that if adjustment is not perfect, the brush is likely to clamp a hand or foot to the runway rail instead of pushing it away.

Crane walks should be substantially built and should be above the bridge drive shaft if possible. If this is not possible, the shaft, motor, gears, &c., should be safely guarded. The walk decking preferably should be of chequered steel plating. Railings should be substantial and of proper height with a toeboard to prevent tools of repairmen and other objects from falling.

Crane cabs or cages should be commodious and equipped with proper railings, toeboards, enclosed resistances, switches that can be quickly cut-out, and that can be locked while repairs are being made. All controller levers, counterweights, &c., should be securely fastened to prevent parts from becoming loose and falling.

A craneman should never be allowed to operate a crane until he has passed a satisfactory physical examination, and is known to be free from physical defects, and is not addicted to the use of drugs or alcoholic liquors. He should be thoroughly acquainted with every detail of the crane equipment, and understand the proper uses of same. Cranemen should never attempt to make adjustments of any kind while the crane is in motion. A craneman, in violation of this rule, was running a crane equipped with a sandbox. The sand was not running as freely as he desired, and he reached up while the crane was in motion to shake the discharge pipe, and the bridge wheel ran on the projecting end of a finger of his glove and before he could jerk his hand away the wheel crushed off the end of several fingers.

Repairing or oiling should not be allowed while cranes are in operation. Workmen performing these operations should place their lock on the cut-out switch to ensure their safety and the safety of others, and the lock should remain there until the work is completed. An instance may be cited

* Paper presented at fifth annual safety congress of the National Safety Council, Detroit, U.S.A., October 17th to 20th, 1916.

wherein a repair gang was working on a crane trolley, but had not locked the cut-out switch. Before the repairs were completed a hurry-up call came to repair a crane that had broken down while pouring a heat, and the gang quit work on the first crane to go to the second one, leaving a gear from the trolley lying on top of the girder. The men left no sign or other notice that the job was uncompleted. Before the repair gang returned, the crane was needed and a craneman was ordered into the cab, and he started to move the crane trolley, with the result that the gear lying on the girder was brushed off, and fell on the head of a workman below.

It is interesting to know that such accidents seldom result from a single cause, but are usually the result of a train of failures to do the proper thing. Cranes should be inspected daily by someone who is assigned regularly to that work, and a craneman should no more think of starting on the work of his turn without giving his crane an inspection than a locomotive engineer would think of starting on a run without inspecting his locomotive.

In making repairs to cranes, repair men frequently, in carrying repair parts to the crane, travel along the crane runways. This practice should be discouraged, if possible, and other means or routes should be taken, as this is one of the points where serious accidents frequently occur. If this practice cannot be obviated, every precaution possible to prevent an accident should be taken, and sufficient warning or notice to all the crane operators on the runways should be given.

It is frequently necessary for workmen to be on portions of crane runways while installing equipment in a shop. When this occurs the portion of the runway in use should be protected by clamps attached to the runways that will prevent cranes from running to that position, and constant vigilance by foreman and safety men should be exercised to see that such precautions are maintained at all times.

In installing a set of swing girders in a certain shop, it was found necessary to attach shafting to the bottom of the girders supporting the crane runway. The work was being done after the regular work hours in that department, and all parties had been notified every time the work was undertaken and clamps had been attached to crane runway rails. The work was nearly finished, and on the last evening the erecting men concluded that they would not take the trouble to put on the clamp stops as things seemed quiet in the shop.

The foreman in the shop had occasion to move a casting and ordered a man up into a crane who was not regularly employed in that portion of the shop, and he knew nothing of the work that was being done on the crane runway. The crane was started, and, as there was no warning signals, the crane operator did not observe the workmen on the opposite runway from the cab, and, there being no stops on the rail, he ran into the men before they could get out of the way or before he could stop the crane, killing one man and seriously injuring another.

All chains used in connection with cranes should be carefully adapted to the need of the service that they are to be used in, and should be made of the best grade of iron obtainable. Most shops are short on crane service, and to overcome this shortage heavier loads are handled than should be. To do this longer chains are constantly being slipped into service by the shop foreman, with the result that workmen are in constant danger of an accident due to a failure of one of the strained links. Most chains are made of lighter material than should be allowed for the loads that are to be handled. For these reasons if careful attention is paid to the length of the chains, and if they are kept as short as possible, a safety feature is established that is not always recognised. An easy way to determine whether chains are strong enough for the service required is to anneal the chains. If after annealing the chain links continue to hold their original contour or shape in service it is certain that the chain is strong enough. If the links become elongated, and the chain as a result becomes ropy or stiff, the chain is not as strong as it should be. This test is the only reason for annealing chains. Most crane sling and hook chains in foundry service are made of ⅝in. stock which is a handy size to grasp and is easily handled by the chainman.

When a chain comes from the maker the links have a property or quality that has been imparted to the metal in the manufacture that seems to be what may be termed a temper, although the carbon contents of the iron or steel is so low that it is negligible. When a link of this new chain breaks, it snaps without warning, and with a crystalline fracture which shows that it has hardness. Take two pieces of new chain and anneal one, then pull both on the testing machine, and the annealed piece will show far more elongation, and will break with a fibrous fracture, giving visible warning before breaking; the unannealed piece of chain will show tensile strength of several hundred pounds over the annealed piece, but will break with very little elongation and without warning. This extra strength is a false element and is the cause of many accidents.

It is the opinion of the writer that annealing does not correct defects in chains, unless they have been subjected to overheating, and that seldom occurs in foundry practice. Annealing does not mend or cause the minute separations that follow overloading to reunite, and the annealing of a chain would never be attempted if it was not for the fact that annealing removes this false element of strength, due to hardness, and reveals the fact that light weight chains are being used in such a way that foremen and men cannot overlook the evidence.

The use of chains is always attended with danger on account of the links parting without notice, pinching the hands and fingers of chainmen, and causing other injuries. The person who finds a way to use cable for sling material will be a public benefactor. To prevent an injury to the hands of chainmen the use of leather mitts should be encouraged, as the mitts prevent the fingers from getting into the links, and allows the hand to be withdrawn if the mitt is caught at any time.

As has been previously stated, there is a tendency to handle excessive loads, and care and constant supervision are necessary to prevent this practice. If there is any uniformity of the materials to be handled, this simplifies the matter greatly. Chainmen should be instructed never to lift a miscellaneous load—such as different sized flasks—if it can be avoided, and the craneman should be instructed to refuse to move a load that he considers dangerous. This rule may cause some friction, but it is better to be safe than sorry, as the slogan goes.

A proper method of communication between chainmen and cranemen is one of the essentials in crane operation. If chainmen work in pairs there should be a senior chainman, who should give all signals, and the craneman should take signals from him only. Many shops provide whistles for the chainman to give signals with, but signals given manually are preferable, especially if more than one crane is in operation in a shop at a time, as there is less likelihood of a wrong signal being given or of the signal being misunderstood.

Some cranemen seem to be unfortunate in that they have more accidents than their fellow-workmen. A record of accidents under each craneman, when analysed, will often reveal where the cause of this seeming misfortune lies, and it will usually be demonstrated that the unfortunate craneman is an inefficient one. To obtain efficient crane service, it is necessary that careful attention to all the details of crane operation be given, and cranemen, chainmen, and others must follow without deviation the rules that are adopted for their guidance and government, if accidents are to be prevented.

Preparation of Bituminous Coal in Illinois.—An extensive study of the methods employed in the preparation of bituminous coal at Illinois mines has been made by the Engineering Experiment Station of the University of Illinois. The data and information which have required several years to compile have been tabulated and analysed by Prof. E. A. Holbrook, and are now published as Bulletin 88 of the Engineering Experiment Station. The results are sub-divided into (*a*) evolution of present preparation practice, (*b*) standard types of tipples or preparation plants, (*c*) impurities and breakage of coal, making preparation necessary, (*d*) sizing and sizes of Illinois coal. A record is presented of the yearly production of the different sizes of coal in Illinois over a period of 35 years, agreements between operators and miners as affecting preparation are discussed, and requirements for standardisation are studied. Copies of the bulletin may be obtained upon application to W. F. M. Goss, director, Urbana, Illinois.

LOCOMOTIVE FIREBOX EFFICIENCY.*

BY J. T. ANTHONY.

ORDINARILY in speaking of locomotive boiler efficiency, we have in mind the overall efficiency of the entire boiler. This depends on the rates of the heat contained in the steam generated to total heat in the coal as fired. Such a definition makes no distinction between the heating surface efficiency and furnace efficiency, nor does it locate the different heat losses and charge them to their true sources.

In order to make an intelligent study of the locomotive boiler, with a view to possible improvement, it is necessary that we consider separately the functions of the furnace and the heating surfaces. Primarily, it is the function of the furnace to liberate the heat contained in the coal and make it available for absorption. Furnace efficiency then would be the ratio of the heat liberated to heat contained in the coal. It is the function of the heating surfaces to take up the heat so liberated and convert the water into steam; the efficiency of the heating surfaces being measured by the ratio of the heat absorbed to the heat available for absorption, though we might say in passing that this is not the true heating surface efficiency since part of the heat liberated in the furnace is not available for absorption by the heating surfaces.

"Firebox efficiency" is a term more difficult to define; for the firebox performs not only the functions of the furnace in liberating heat, but it also contains part of the heating surfaces and absorbs a material portion of the heat liberated. It is easier to determine the efficiency of the furnace and grates than it is to determine the efficiency of the firebox heating surfaces. However, it is the main function of the firebox to liberate the heat contained in the coal; and, as will be shown later, the efficiency with which it does this will have a very material effect upon the efficiency of the firebox heating surfaces.

The chart, Fig. 1, shows in a general way distribution of the heat losses on a modern locomotive equipped with brick arch and superheater, and burning a high volatile coal, under hand-fired conditions. The figures at the left show the percentage of the heat lost or absorbed; while those at the bottom show the pounds of coal fired per square foot of grate surface per hour. It will be noted that as the rate of combustion increases, the heat losses increase.

Losses due directly to the furnace can be summarised as follows: First, incomplete combustion and the formation of carbon monoxide; second, sparks and cinders; third, combustible in ash; and fourth, radiation and unaccounted for. It is very clear that the losses due to incomplete combustion, sparks and cinders, and combustible in ash can be charged directly to the furnace, as they represent a part of the heat in the coal that is not liberated by the furnace.

It is possible that a large proportion of the heat loss due to radiation and unaccounted for can also be directly attributed to the furnace. Radiation losses from a well-lagged boiler shell are not great. The radiation losses from the fuel bed through the grates into the ash pan are difficult to determine. It is possible, however, that owing to the interference of the grates and to the inrush of cold air through the grates, this loss also is small. The unaccounted-for losses are those due to the escape of unburned hydro-carbon gases which are not detected by the ordinary gas analysis; and to possible errors that do not account for all the losses due to incomplete combustion, sparks, cinders, &c.

If we ignore the losses due to radiation, the sum of the losses enumerated will represent the total heat loss due to the furnace; and the furnace efficiency line, as indicated in Fig. 1, will run from about 95 down to 60 per cent. at the highest rate of combustion. In other words, in burning 30lbs. of coal per square foot of grate per hour, the furnace will liberate 95 per cent. of the heat contained in the coal; while when burning coal at the rate of 180lbs. of coal per square foot of grate per hour, the furnace will liberate only 60 per cent. of the heat contained in the coal.

The boiler efficiency line, shown as running from 80 down to 40 per cent., represents the amount of heat absorbed by the boiler and contained in the steam. The space between furnace efficiency and boiler efficiency lines represents the front end heat loss that is partly chargeable to the heating surfaces (these losses being due to heat in the dry front-end gases); to moisture in the air and coal, and to moisture formed by burning hydrogen contained in the coal.

Since we are at present concerned with the question of furnace efficiency, we shall briefly study the different heat losses that determine it. The heat losses under incomplete combustion, allowing the formation of carbon monoxide, range from zero at low rates of combustion to 8 per cent. at the rate of 180lbs. per square foot of grate. Of course it is understood that this is an average, for there is a wide variation in losses due to this source. Primarily, we might say that the formation of carbon monoxide is due to the absence of sufficient air or oxygen above the fire, or to imperfect mixing of the gases in the combustion chamber space. The amount of air supplied per pound of coal, other things being equal will vary with the thickness of the fuel bed; and as this thickness increases with the rate of combustion, it follows that the air supply will be reduced as the rate of firing is increased, and the chance for the formation of CO will be increased proportionately.

The method of firing also has an important bearing on this. With a light, level fire and coal of a uniform size, the air distribution through the fuel bed will be uniform, and there will be a better chance for every particle of combustible coming in contact with the required amount of oxygen, resulting in complete combustion. If we have the conditions of a heavy bank of green coal under the door and a hole in the front of the fire and no arch, it is readily seen that incomplete combustion and the formation of CO is permitted. A bank of green coal under the door results in a large volume of hydrocarbon gases being distilled off, while the air supply through that portion of the fire is reduced. Without the baffling or mixing furnished by the arch, the tendency is for these gases to pass up along the crown sheet and into the top flues, for the most part unburned. A front end gas analysis under these conditions would show a large excess of oxygen, due to the large volume of air rushing through the hole in the fire; and at the same time would probably show a high CO content, due to incomplete combustion of the hydrocarbon gases and the incomplete burning of the CO formed in the fuel bed.

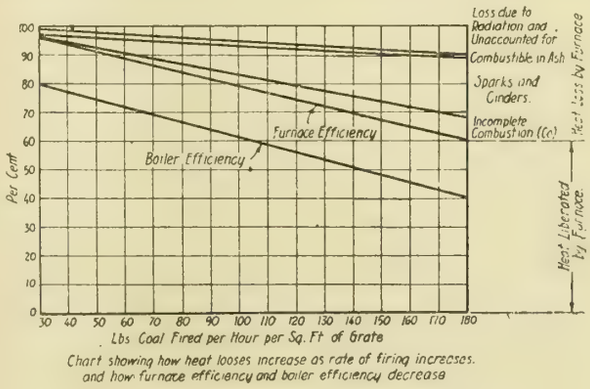


FIG. 1.

It is probable that air entering through the grates and coming in contact with the glowing coals at the bottom of the fuel bed, first forms carbon dioxide; which, on passing up through the fuel bed, is reduced to carbon monoxide by coming in contact with other particles of the glowing carbon. This carbon monoxide issues from the top of the fuel bed as a gas; which can be completely burned to carbon dioxide, if brought in contact with the necessary amount of oxygen and given time to mix and burn before entering the flues. The hydrocarbon gases driven off from green coals thrown on the fire consist (as the name indicates) of carbon and hydrogen. The hydrogen has a greater affinity for oxygen than carbon; and breaks away from the carbon and combines with the oxygen to form steam. If there is ample oxygen present, the carbon will also combine with it and will be completely burned to carbon dioxide. If the oxygen supply is insufficient, it will

* Paper read before the Richmond (U.S.A.) Railway Club, October 16th, 1916.

be incompletely burned to carbon monoxide; or else will be thrown down as solid particles of carbon which float in the flame, giving it its bright colour—and eventually escape at the front end, causing smoke, or will be deposited in the flues as soot.

Bituminous coal contains from 25 per cent. to 50 per cent. volatile matter, which burns above the fuel bed as a gas. In addition, it would seem that a large portion of the fixed carbon on the grate is first completely burned to carbon dioxide

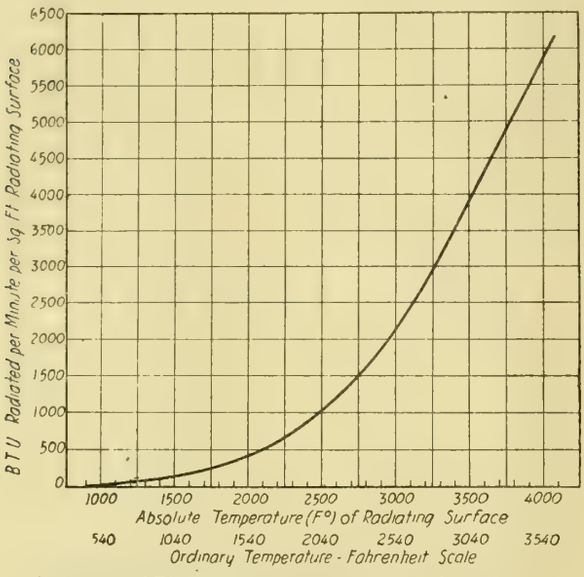


Chart showing B.T.U's radiated per minute per sq ft of radiating surface when temperature of fireside of firebox sheets is 440°F or 900° absolute

FIG. 2.

and then reduced to carbon monoxide—which leaves the fuel bed as a gas, and can be burned completely, if mixed with sufficient oxygen. It is evident, therefore, that a large part of the fuel burns in the form of gas; and in order to burn it completely, it is necessary to make proper provisions—the chief of which are efficient mixing and ample combustion chamber space.

When different gases are brought together in a vessel, they will mix evenly and uniformly by diffusion; but the conditions that prevail in a firebox do not permit of such action taking place there, to any large extent. The time the particle of gas remains in the ordinary locomotive firebox will vary from one-quarter to one-tenth of a second, depending on the amount of coal being burned, the volume of gases being driven off, and on the volume of the firebox. When we remember that there may be eight or nine different gases issuing from the fuel bed, and consider the volume of the firebox (which may be 300 cub. ft., more or less—generally less), and the length of time available for mixing, it becomes very evident that we cannot safely depend upon gases to mix by diffusion; and it is necessary to mix them by some artificial means—such as an arch.

Spark and cinder losses will vary with the nature of the coal and with the draught. A run-of-mine coal containing a large amount of slack will produce more sparks and cinders, under the same conditions, than will a lump coal free from slack. The large increase in sparks and cinders as the rate of firing increases is due principally to the increase in the draught. At low rates of combustion, the draught is low and velocity of the gases in their travel from the fuel bed to the flues is relatively low. As the rate of combustion increases, the draught increases and the velocity of gases increases. The velocities of the gases passing through the locomotive firebox will range from 100ft. to 30ft. per second—or as much as 200 miles per hour. We can easily imagine the effect of such a cyclone upon the fine particles of coal; and it is not difficult to understand why such a large percentage of the coal is picked up by this fierce draught and swept out of the firebox through the flues, unburned.

The loss due to combustible in ash is small, and decreases as the rate of combustion increases. This is due to the increased draught offering more resistance to the small particles of fuel falling through the grates. This loss cannot be entirely eliminated, but can be reduced to a minimum by making the air openings through the grates of a size suitable to the physical characteristics of the coal to be burned.

We have seen from the above that in order to get high furnace efficiency it is necessary to have grate area large enough to keep the rate of combustion low; to have a uniform and ample air supply; to have efficient baffling and gas mixing devices; and to provide combustion chambers of ample proportions. Any increase in grate area which enables us to carry lighter fires and thereby enables us to get a uniform air supply, will be partly neutralised if insufficient air openings are provided through the ash pan and grates. Some roads have adopted a standard of 14 per cent. air openings through the ash pan—that is, ash pan air openings are 14 per cent. of the grate area. This amount of opening is probably sufficient at low rates of combustion; but at high rates, draught gauges indicate almost 1in. of vacuum in ash pans with this amount of air opening. It would seem, therefore, that in order to get atmospheric pressure in the ash pan (which is desirable), the air opening in ash pan should be increased to probably 20 per cent. of the grate area—particularly on locomotives that are forced to their capacity.

Let us now see what effect the above-named factors have upon the effectiveness of the firebox heating surfaces. These heating surfaces receive their heat by radiation and by convection, the latter playing but a small part. By "radiation," we understand that the heat travels directly from the radiating surfaces to the heating surfaces, without the aid of any material agency; that is, the heat travels by rays just as light does, and will travel through a vacuum in the same manner as light. By "convection," we are to understand that the heat is conveyed by means of some material agency, such as air or the gases of combustion. The amount of heat radiated to the firebox heating surfaces depends upon the difference in temperature between the radiating surfaces and the firebox heating surfaces; and upon the area or extent of the radiating surfaces. In a locomotive firebox these radiating surfaces consist of the grate, when covered with live coals, the luminous flames, and the hot brick-work which it may contain.

According to a well-known law, a hot body (such as a fuel bed) entirely surrounded by a black body (such as the firebox soot covered sheets) will radiate a certain amount of heat per unit of time per square foot of radiating surface, the amount so radiated being equal to a constant times the difference between the fourth powers of the temperatures of the radiating surfaces and the heat-receiving surfaces. These tempera-

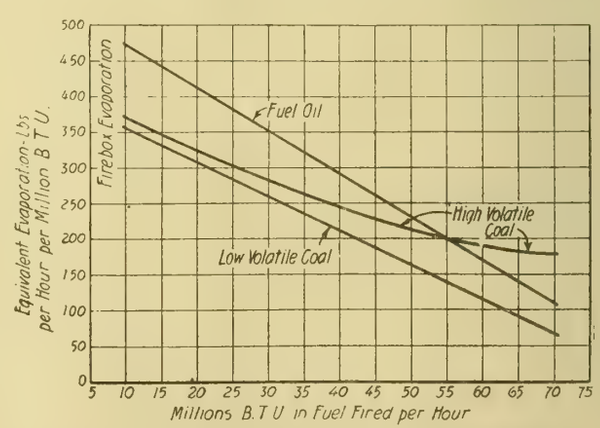


Chart showing effect of different fuels upon firebox evaporation, and illustrating the influence of flame upon the amount of heat radiated.

FIG. 3.

tures are absolute, that is, temperatures equal to the ordinary temperatures, as read on the Fahrenheit scale, plus 460°. In studying the action of gases under temperature scientists have discovered that there is a constant relation between the temperatures and the volumes. From this, they evolved the theory that if we cool a gas to a sufficiently low temperature the volume would entirely disappear, or become zero. This theoretical temperature was called the "absolute" temperature. It is equal to 492° below freezing, on the Fahrenheit scale, or 460° below zero. It is hardly necessary

to say that this absolute temperature has never been reached.

By using as the temperature of the firebox sheets 400° Fah., or 860° absolute, the chart in Fig. 2 has been plotted to show the B.T.U. radiated per minute per square foot of radiating surface at different temperatures of the fuel bed. At an absolute temperature of 2,100° each square foot of fuel bed radiates 500 B.T.U. per minute. By increasing it to 3,000° absolute we get more than four times as much radiation. It is evident from this that a small increase in firebox temperature will have a marked effect upon the amount of heat radiated and upon the evaporation, and while a reduction in the temperature of the firebox heating surfaces will also increase the amount of heat radiated it does so to a very much smaller extent, and the opportunity for increasing the firebox evaporation by reducing the temperature of the heating surfaces is very small. The principal means of increasing firebox evaporation is by increasing the temperature of the radiating surfaces, or by increasing their area. From this it follows that increasing firebox heating surfaces without increasing heat-radiating surfaces will have little effect upon the firebox evaporation.

Flame radiates heat; and it would be a logical supposition that increasing the mass of flame in the firebox would increase the amount of radiant heat given off. Such seems to be the case. Increasing firebox heating surfaces generally increases firebox volume. This can be accomplished by increasing the depth or width of the firebox, or by adding combustion chambers. The amount of flames in a firebox will depend primarily upon the amount of combustible gas being driven off, the air supply, and the volume of the firebox. If the amount of gas being burned is sufficient to completely fill the firebox with flame, the effective flame-radiating surfaces will practically equal the exposed heating surfaces of the firebox. In other words, when the firebox is completely filled with flame the flame-radiating surfaces can be considered as an envelope or film, virtually in contact with the firebox heating surfaces at all points. If these conditions are fulfilled it follows that the area of the flame-radiating surfaces will equal the area of the firebox heating surfaces.

As we have seen, increasing the heating surfaces increases the volume, and if this added volume is filled with flame the increase in radiating surfaces is proportionate to the increase in heating surfaces. If the additional volume so gained is not filled with flame, there will be little or no increase in firebox evaporation—though, of course, any increase in volume promotes combustion of the gases and adds to the efficiency of the firebox. The effect of the heat radiated by flames on firebox evaporation is graphically shown by the chart in Fig. 3. In this test the same boiler was tried out with fuel oil, high volatile coal, and low volatile coal, and an accurate determination was made of the amount of steam evaporated by the firebox heating surfaces, and the tube-heating surfaces, in each case.

In order to make these different fuels strictly comparable the data have been plotted on the basis of millions of B.T.U. fired per hour, and the equivalent evaporation figured in pounds per hour per million B.T.U. contained in the fuel. It will be noticed that the fuel oil gives a very much higher firebox evaporation per heat unit contained than do the high volatile or low volatile coals. The high volatile coal ranks second, while the low volatile coal is last. In the case of the oil, the heat was radiated from the flames and the brickwork in pan. With the high volatile coal, the heat was radiated from the fuel bed and from the long flames. With the low volatile coal, the heat was radiated from the fuel bed and the flames, which were shorter and more limited in extent. The higher evaporation obtained with the oil may also be partly explained on the score of higher temperatures, and the efficient burning of the oil, resulting in small heat losses, and the utilisation of practically all the heat contained in the oil for evaporative purposes. When using coal, the heat losses are considerably higher, and this would, of course, tend to reduce the number of heat units available in the firebox for producing steam.

The curves in Fig. 4 show the equivalent evaporation per hour from the firebox heating surfaces, tube heating surfaces, and total boiler heating surfaces, as the rate of combustion increases from 30lbs. to 150lbs. of coal per square foot of grate per hour. This boiler had 58 sq. ft. of grate, 175 sq. ft. of exposed firebox heating surfaces, and 2,800 sq. ft. of tube-heating surfaces. It will be noted that at the low rate of 30lbs. of coal per square foot per hour firebox evaporation was 50 per cent. of the total, while at the higher rates it was less than 30 per cent. This is due to the fact that firebox temperature increases slowly as the rate of combustion increases; and, finally reaches a point where any further increase in the amount of coal fired would cause a reduction in temperature due to the inability of the furnace to burn it, and a consequent reduction in firebox evaporation. The fuel bed radiating surfaces remain constant, but as the rate of combustion increases the mass of flames increases, up to a certain point. When the firebox is completely filled with flame, it is obvious that no further increase in evaporation can be obtained from this source.

Tube evaporation depends upon the weight, temperature, and density of the gases passing through. As the rate of combustion increases, the temperature increases slightly, with a consequent decrease in density, and the weight increases almost in proportion to the increase in the amount of coal fired. That the tube evaporation is not exactly proportionate to the amount of coal fired is due to the fact that as the rate of combustion increases, the air supply per pound of coal decreases, resulting in decrease in the weight of the gases evolved per pound of coal.

Heat losses increase rapidly at the higher rates; and the amount of coal fired to the amount of coal burned varies

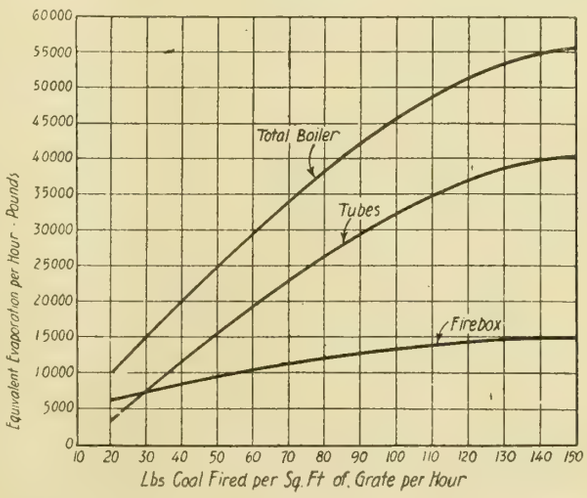


Chart showing the effect of increasing the amount of coal fired. upon the equivalent evaporation from the firebox and tube heating surfaces.

FIG. 4.

quite widely. At the rate of 120lbs. of coal per hour, the curve indicates that the firebox had an equivalent evaporation of 14,500lbs. of water per hour. If we assume that the average temperature of the fuel bed at this rate of combustion is 2,140° Fah. or 2,600° absolute (which is about as high as we can expect under average conditions), about 1,200 B.T.U. will be radiated per minute from each square foot of the radiating surfaces.

In a given case the grate area was 58 sq. ft., covered with incandescent fuel, to which should be added the flame-radiating surfaces. The exposed firebox heating surface was about 175 sq. ft., and, as the firebox was not equipped with an arch or baffle of any sort, it was not completely filled with flame. It was assumed that this flame-radiating surface was 75 per cent. of the exposed firebox heating surface, or 130 sq. ft. This, added to the 58 sq. ft. of grate area, gives 188 sq. ft. of radiating surface, which is radiating 1,200 heat units per minute, or, the total amount of heat radiated per hour will be more than 13½ million B.T.U., which is sufficient to give an equivalent evaporation of 14,000lbs. of water. This leaves a difference of about 500lbs. of water, which can be ascribed to heat taken up by convection, or by the actual contact of the hot gas with the firebox heating surfaces. This may seem to be an abnormally small amount of heat to be taken up by convection, but it should be remembered that in order to get the heat from the gases into the heating surfaces it is absolutely necessary to bring the molecules of hot gas into actual contact with the heating sur-

faces: and to do this, it is necessary to break up the gas into small streams, completely surrounding these small streams with cooler heating surfaces.

The above conditions are not fulfilled in the locomotive firebox. The cross-section area of the firebox and gas stream is so great, and its length is so short compared to the actual firebox heating surfaces, that the amount of heat taken up by convection becomes almost negligible. The fact that gases in the firebox are high in temperature has but little value, for the high temperature is of no benefit unless the gases can be brought into actual contact with the heating surfaces.

It is evident from the foregoing that the factors which tend to increase the effectiveness of the firebox as a heat liberator also increases its effectiveness as a heat absorber. Increasing the grate area and reducing the rate of combustion reduces the cinder losses and makes it possible to carry a lighter fire, thereby securing a more uniform air supply and better combustion. At the same time, an increase in the grate area increases the radiating surface and thereby increases the firebox evaporation. Increasing the firebox volume by adding a combustion chamber promotes the combustion of the gases and reduces the heat losses due to carbon monoxide and the escape of unburned hydrocarbon gases. If, in addition, the combustion chamber is filled with flame, the radiating surface is increased correspondingly, and the firebox evaporation also increases.

The addition of a bridge wall or arch tends to reduce the heat losses due to cinders, unburned hydrocarbon gases, and the formation of carbon monoxide. At the same time it increases the heat-radiating surfaces, and, by compelling all the flames and gases to pass back and over the arch, tends to completely fill the firebox with flames, thereby still further increasing the radiating surface and the firebox evaporation. The installation of this refractory brick-work in the form of a wall or arch also tends to hold the firebox temperatures at a more uniform level, and reduces troubles brought about by the sudden contraction of firebox sheets when fire is dropped and temperatures are suddenly reduced.

Some progress has been made along these lines in recent years, but it is possible that future progress will depend upon the use of still larger fireboxes, larger grates, increased firebox volume and longer combustion chambers.

ECONOMY OF COAL IN POWER PRODUCTION.*

BY C. E. STROMEYER, M.INST.C.E.

THE present war, with its accompanying high prices and the possibility of a trade war after the conclusion of peace, has naturally directed attention to many economic questions, including boilers, and though, in last year's memorandum, I made a few remarks about their economic working, the present occasion seems an opportune one for re-examining this question from a national point of view.

Discussions about the difference between English and German economic systems of working factories have revealed that abroad a much greater harmony existed between the State and manufacturers than here, and, as a consequence, German works have adopted systems which commended themselves because of their leading to national economy, whereas here both our laws and our customs seem to force individual works to think more of themselves than of the country's welfare. Here we need only concern ourselves with the fuel question, which is briefly as follows: Our manufacturers have been spoilt by the ease with which they could obtain the very best coal in the world. When new labour-saving appliances were invented which, while increasing the output, also increased the power required to drive them, the manufacturers filled their works with them and overworked their boilers, and as this could only be done with the best of coal, slack was for long periods a drug in the market and at one time sold for 5s. or 6s. a ton at the pit's mouth; for at that time none of our works could burn it economically.

Constant improvements in mechanical stokers have effected a change, but no overworked boiler can burn dirty coal, no matter whether it be fed by hand or by mechanical means, and slowly but surely colliery owners found that it did not pay to bring inferior qualities of coal to the surface. As most coal seams consist of several layers, of which some are rich and others poor, the poorer layers of worked seams are often left underground and buried for ever, because to mix them with the richer ones would disproportionately lower their value.

According to recent statements by coal experts this wasted coal amounts to 25 per cent. of our output. This national waste is due largely to our almost universal practice of overworking boilers. Bunker coal for steamers must, of course, be as free as possible from mineral matter, and export coal has also to be reasonably pure, but there is no reason, except want of boiler power in our factories, why inferior coal should not be burnt wherever it can be got. It is done on the Continent, because first-class coal cannot be obtained, but there the works provide themselves with ample boiler power, and on the whole they obtain a higher efficiency than we can hope for with our superior coal but hard-worked boilers.

Somewhat similar remarks might be made about the burning of coke. It is a by-product of the gas works of towns and might with gas be a valuable by-product of works which would make it their business to produce sulphate of ammonia and the volatile oils of distillation. Coke ought, therefore, to be a cheap fuel. At present, however, its production is limited, and those consumers who are compelled to use it as a fuel can be made to pay so heavy a price for it, that the profits can be used for relieving the rates. Steam users naturally do not like coke, partly on account of its relatively high price and partly because it would require larger boilers than the present ones in which to burn it with as good effect as the best coal. Thus, here again, our habit of getting the highest possible duty out of our boilers may be looked upon as being one of the causes, though perhaps only a secondary one, which hamper our coal-tar industry.

Our present practice may possibly be more profitable to the individual factories and collieries than to those of the Continent, though this is a moot point, but there can be no doubt that this practice is very wasteful of our national coal resources, and it is to be hoped that after the war encouragement will be held out to those who, without loss to themselves, will assist at national economy.

Take the simple case of a shipowner who has to decide for what speed a ship, which he contemplates ordering, should be designed. He knows that with a low speed his ship cannot command paying freights, and, going to the other extreme, he also knows that if he fills his ship with engines and boilers, there will be no room for cargo, and his coal bill will be far in excess of his earnings. He will, therefore, have to decide on a medium speed which here may be assumed to be 10 or 11 knots. With the faster ship he will be able to make 10 per cent. more voyages than with a slower one, but his annual coal bill will be increased 20 per cent. and his carrying capacity slightly decreased, on account of the extra 20 per cent. of engine, boiler, and bunker capacity. Leaning on past experiences he may be able to say to himself that his prospective earnings would be about the same, no matter whether he were to decide on the 10 or the 11-knot boat. At this point national economic considerations ought to influence him, and he ought to say to himself: The 11-knot boat will carry 10 per cent. more cargo than the 10-knot boat, but it will burn 20 per cent. more coal. My profit will be the same with either speed; therefore, in order to assist my country in saving coal, I will decide to have the slower boat.

The factory owner is faced with other, but similar, problems, and will find that he too can make selections amongst a number of alternatives of which he should choose the one which, while it does not affect his profits, will be of economic advantage to the nation. It will be my endeavour to review these several alternatives.

The cost of fuel depends, of course, on the cost of labour, and that depends on the average cost of living. This will necessarily be increased after the war on account of the heavy taxation to which we as a nation will be subjected; but it is impossible to make even the vaguest guess as to the extent to which future prices of fuel will be affected by the increased cost of living. For convenience of illustrating the subject a pre-war price of 12s. 6d. per ton will therefore be

* From the memorandum by the Chief Engineer of the Manchester Steam Users' Association for the year 1915.

used as a basis of the present calculation. We may assume that the coal consumption for a first class modern steam engine can be reduced nearly down to 1lb. of coal per indicated horse-power, or nearly 4 tons per year continuous working. In most factories only about one third of the full time is worked, whereas the interest on capital is a continuous charge, and the total cost, including wear and tear, was in one modern factory found to be £12 per indicated horse power per annum, at a time when the cost of fuel was 12s. 6d. per ton. Had the factory been working night and day the cost would have been £6 per indicated horse-power per annum.

This compares very unfavourably with 35s. to 50s. per electric horse-power, which is approximately the cost of continuous-power production in some parts of Sweden, Norway, and on the slopes of the Alps. These districts are rapidly realising that they can control enormous powers, and when these have been harnessed they are sure to attract to themselves many of our industries. After the war wages in this country are likely to rise, and the disproportion is likely to be increased.

Then also, as America is not going to burden herself with additional taxes, the cost of living will not be increased in that country. But the most threatening possibility is that Prussia, true to her national traditions, not to be saddled with a national debt (her present one of 600 millions being merely an industrial one created when the State acquired all the railways), may repudiate all her internal war loans, and after a few years of severe personal hardships, the taxation in Prussia, and consequently the average cost of living and with it the price of labour and of coal, will be as low as before the war.

We may therefore expect that some time after the war our cost of creating power for industrial purposes will be greater than in other countries, so that even without considering the question of economising our national coal resources, it will be necessary for individual works to practise extreme economy as regards coal consumption.

In order to be able to reach a reliable starting point as to possible fuel economies, a table of engine performances is given in the memorandum which is not here reproduced. The deductions which can be drawn from that part of the table dealing with cotton spinning mills are, roughly speaking, that compound engines using steam of 100lbs. pressure consume about 3·0lbs. of coal per indicated horse-power. For high-pressure compound engines, the net consumption is about 2·15lbs. of coal per indicated horse-power, and for triple-expansion high-pressure engines it is about 1·65lbs. of coal per indicated horse-power. These results are neither as good as the results promised by engine builders nor as those attained during trials. This is but natural and should not be allowed to influence intending purchasers, for it must be remembered that a factory engine stands idle for two-thirds of its time and that the raising of steam and the banking up of fires costs much fuel, say 0·3lb. per indicated horse-power. If we make this further deduction we arrive at the following average net consumptions per indicated horse-powers under ordinary working conditions, which are, of course, never as favourable as trial conditions, at which the makers attend and try to minimise all losses.

Old compound engines working with about 100lbs. pressure consume about 2·70lbs.

High-pressure compound engines consume about 1·85lbs.

High-pressure compound engines with superheated steam consume about 1·45lbs.

Triple-expansion engines consume about 1·33lbs.

The figures given in the table show that as a rule only about 1lb. or 2lbs. of coal per indicated horse-power, or, say, £1 to £3 per annum is likely to be saved by modernising an old power plant. If, in addition, arrangements were to be made, by providing ample boiler power, for burning cheaper quality of coal, a very great monetary saving might be effected, but unless collieries will provide inferior fuel to individual works, this desirable policy can only be carried out by large combinations of power producers.

The Newcastle Electric Supply Company has in a way shown what can be done in this direction, and their work has also revealed the difficulties which would have to be overcome in other districts than their own before success can be obtained. Their leading idea seems to have been to provide trunk wires which would do for power what railways do for goods. They provide collieries and ironworks with outlets for any power which may be produced from their waste coal and from the waste heat of their furnaces, and they thus provide the means for the sale of this power which would otherwise be wasted. This company has in some respects been favoured by local conditions, but it had also to contend with serious difficulties which are even more serious in other districts. It had the advantage of promises from all the large works on the Tyne to buy power from them, and its first power stations could therefore be designed to work with large units and with a minimum of cost. Subsequently the North-eastern Railway Company agreed to purchase all its power for local traffic. On the other hand, the Board of Trade limit on the voltage in the trunk wires made these connecting links very expensive, and as nearly every old power station had its own voltage and its own frequency of phase, practically every amalgamation necessitated the erection of entirely new installations. An initial difficulty, which has, however, been nearly overcome, was that the numerous Corporations had the right to exclude outsiders from supplying their little districts with power. But they have seen the advantage of adapting their voltages and frequencies of phase to those of the company, and now they buy their electric power from it for the purpose of distributing it amongst their customers.

As far as can be ascertained, the charge per unit of electricity, if used all the year round without a break, has been reduced to about £4. 10s. per electric horse-power. For 8-hourly supply the charge would, of course, be much heavier, possibly as heavy as the cost of individual power production by a modern steam engine. One reason why power can be produced thus cheaply, is that the company with its network of transmitting wires can deal with collieries on the following lines: Each colliery can bring or brings to bank some very dirty coal or shale, which is absolutely unsaleable. Of this fuel about 25 per cent. can be burnt in the colliery boilers, but the remainder is thrown on waste heaps and is occasionally burnt there. Now the company, by installing a power station with ample boiler power close to the collieries, could consume all this apparently valueless fuel and produce four times as much power as was needed by the colliery. The colliery buys its quarter share and the rest is carried away in the trunk wires. Ironworks are utilised in the same way. The heat wasted by the gases which escape from blast and other furnaces is far in excess of the power requirements and was largely wasted, because without a trunk system to carry away the surplus power it could not be used. Now all this waste power is bought at a cheap rate and distributed.

In other industrial districts the conditions for conveying and selling power are rather unfavourable. The numerous Corporations still exclude outside producers from within their boundaries, nor will they buy from outsiders, and they have not the necessary powers for building power stations outside their own districts and thus utilising the waste fuel of collieries. To produce cheap power from fuel which has had to be carted to their own works is out of the question. They also have not the necessary powers for supplying outsiders and are therefore in the most unfavourable position for acting as power brokers or intermediary for the buying and selling of power. What makes matters worse is that nearly every Corporation has its own particular voltage and phase, so that it could not, even if it would, buy and sell power from and to others. The Board of Trade may justly be blamed for this unsatisfactory condition of things, for instead of fixing on comparatively low limits for voltages in trunk lines and encouraging a multiplicity of systems, they might easily have encouraged uniform systems and step by step they could have learned to tolerate higher and higher voltages.

This condition of things is not likely to change until factory owners learn that, with a proper system, they could easily be supplied with power at a cheaper rate than that at which they can produce it. They will then insist on being supplied at as low a rate as is to be found in other districts, and Corporations and other power producers will then be forced to standardise their systems and connect up trunk lines for the conveyance of power.

Another means of distributing power and economising our coal resources is to convert coal into gas, distribute it in pipes, and sell the by-products, thus encouraging agriculture and the coal tar industry. In a certain sense our Corporations work on these lines, and even produce a third by-product—coke. The production and sale of coke might be encouraged more than it is, because it is a smokeless fuel, but here again we find the same conflicts as in the electrical field: Corporation gas is too costly for cheap heating and power production, and producers of power gas are practically prohibited from introducing their pipes into towns.

It might be possible to combine the gas and electricity systems, then gas and its by-products could be produced from waste coal, and this gas could be used in internal-combustion engines, to produce electricity. Unfortunately, however, the gas engine is not as reliable as might be wished, and it is also disliked because of the irregularities of its revolutions which cause flickering of lights and troubles in spinning mills. We have therefore to wait, but possibly not for long, for the perfection of the internal-combustion turbine.

At present the steam turbine seems to combine the greatest number of advantages; not only is its running very steady, but the new designs are reported to be very economical. The most interesting novelty is probably the Lundholm turbine which consists of two discs and blades revolving in opposite directions. As there is no difference of expansion of the two discs there is every prospect that the clearances of the blades can now be reduced to a minimum, and that this very serious source of loss will be materially reduced.

The fuel economy question may therefore be briefly summarised by saying that hardly any improvement is likely to be effected in the economic working of boilers for, as is well known, there is only a margin of about 20 per cent. to 25 per cent. to play with. Considerable pecuniary saving might often be effected by increasing the number of boilers, so as to be able to burn a poor and relatively cheap fuel if this can be got. For instance, if, when best coal costs 20s., dirty coal of, say, 75 per cent. heating value were obtainable for, say, 6s. per ton, the coal bill would be reduced to one-half, but only if the local colliery can bring this dirty coal to bank, and if the boilers are large enough to burn it.

Our chief hopes will therefore have to be centred on engine improvements, for here large savings might be possible, because at present about eight units are thrown away for every one doing useful work. Improvements have been and still are being effected by inventors, and research workers have little scope for their activity. Research workers have already indicated very clearly that the internal-combustion engine can attain a much higher efficiency than the steam engine, but the high cost of the fuel, either oil or gas, nearly balances this advantage, and constant engine troubles and repairs are both annoying and costly. Research workers have also shown that the turbine should be much more efficient than the reciprocating engine, but it is only comparatively recently that the efficiency of the steam turbine has equalled and slightly surpassed that of its older rival, and we look to inventors, rather than researchers, to reduce the remaining losses to a minimum, for the most convenient form of extracting power from coal is still the old method of burning it under a boiler. Central power stations are not limited in their choice to the steam engine for power production, and in view of the very high theoretical efficiency of internal-combustion engines they very likely hope to see the internal-combustion turbine brought to perfection.

From a national economic point of view the combination of the internal combustion engine with electric distribution of power would seem an ideal one. Our collieries would then be encouraged to mine even our dirtiest coal. This coal would produce by-products for farmers and for the coal tar industries and supply the engines with suitable gas, and our factories would receive their power at a lower cost than they could produce it.

British Locomotive Exports.—Exports of locomotives from the United Kingdom continue to decline. The value of the engines shipped in October was £99,910, as compared with £148,901 in October, 1915, and £368,540 in October, 1914.

APPLIANCES FOR HANDLING MATERIAL AT PORTS.*

BY SIR JOHN PURSER GRIFFITH, M.A.I., M.INST.C.E.

(*Concluded from page 371.*)

Casual Labour and Under-employment in Ports.—Those of us who are acquainted with the working of large ports are familiar with the meaning of casual labour and under-employment as associated with the handling of cargoes entering and leaving our ports. There is, of course, under-employment in almost every trade, represented by a fringe of hangers-on, who are employed temporarily to meet emergencies. But in no branch of trade has it assumed such large proportions as in the shipping industries. The fluctuations in discharging and loading of ships in our ports are due to various causes, such as tides, weather, and trade conditions. The docker may earn large wages when work is brisk, and a certain proportion of the dock labourers may have constant employment; but still a very large percentage of the dock labourers come under the class of casual labour, and within that class there are distinct divisions or grades corresponding to varying grades of poverty. Even amongst casual labour earnings are often large, but this is followed almost invariably by periods in which the man does not earn what can, by the utmost stretch of imagination, be called a living wage.

Have you ever witnessed the scenes associated with the engagement of the casual dock labourer? Early in the morning men may be seen making their way to the docks. Most are badly clothed, and many obviously ill-fed. On arrival at the docks they collect in groups at the recognised centres of engagement, or "stands," as they are called. On the appearance of the foreman, whose duty it is to engage men for his employer, they line up, and the foreman selects his men. The selection is first made from old acquaintances, whose powers are known, or for whom he has some special leaning—sometimes for good reasons, sometimes for bad. It has been said that "round each foreman there is a body of men whose chance of employment, like the atmosphere round the earth, grows thinner and thinner, until it diminishes to the vanishing-point at which a man cannot subsist at all. There will be a nucleus of men in practically permanent employment; others further down the foreman's list who will average three or four days a week; and there will be some who will only pick up a scrap of work now and again. This is the daily agony or fate of a man who, from age or some other cause, has lost firm hold of employment."

The sad story of the docker's life is told in Reports of Royal Commissions, books, pamphlets, and magazine articles devoted to the subject. To those interested in it, I would commend a little book, published during the current year, entitled "Casual Labour at the Docks," by Mr. H. A. Mess, B.A. It describes the methods of engagement of the dockers; discusses the consequence of irregular earnings; tells how dock labourers are recruited; refers to past attempts at reform, and makes suggestions for the future. The writer says: "The problem of dock labour is that of chronic over-supply of labour offering itself in response to demands which are irregular as to time, and fluctuate in volume." No suggestion is made in this little book that advantage should be taken of modern machinery and appliances to amend this state of affairs; and yet this is, I believe, a direction in which we should look for relief.

These labour problems have occupied the attention of many thoughtful minds. Much has been attempted to mitigate the lot of the casual docker, with a certain amount of success where employers and workmen have co-operated. This combination is, unfortunately, too rare, and mutual suspicion has barred progress. May we not hope and work for the day when employers will see that liberality towards their workmen will pay better than the old method of trying to get the largest amount of work for the smallest possible wage, and when workmen will see and acknowledge that low output will necessarily result in low wages?

Mr. Winslow Taylor, an American engineer, in his book, "The Principles of Scientific Management," writes as follows: "The great majority of workmen still believe that if they were to work at their best speed they would be doing

* The "James Forrest" Lecture, 1916, delivered before the Institution of Civil Engineers.

a great injustice to the whole trade by throwing a lot of men out of work, and yet the history of the development of each trade shows that each improvement, whether it be the invention of a new machine, or the introduction of a better method, which results in increasing the productive capacity of the men in the trade and cheapening the costs, instead of throwing men out of work, makes in the end work for more men. The workmen of almost every trade have before them an object-lesson of this kind, and yet because they are ignorant of the history of their own trade even, they still firmly believe, as their fathers did before them, that it is against their best interests for each man to turn out each day as much work as possible. Under this fallacious idea a large proportion of the workmen of both countries (America and England) each day deliberately work slowly, so as to curtail the output. Almost every labour union has made, or is contemplating making, rules which have for their object curtailing the output of their members; and those men who have the greatest influence with the working people, the labour leaders, as well as many people with philanthropic feelings, who are helping them, are daily spreading this fallacy, and at the same time telling them that they are overworked. As engineers and managers, we are more intimately acquainted with these facts than any other class in the community, and are therefore best fitted to lead in a movement to combat this fallacious idea, by educating not only the workmen, but the whole of the country, as to the true facts."

The solution generally accepted by those who have devoted attention to this difficult problem is to form a staff of permanent labourers in each port, and reduce the casual element gradually. I can only refer you to what has been done in the Port of Liverpool and by the London Port Authority in this direction. It is only a beginning, but seems to show that the proposition is not impossible or Utopian. Where it has so far failed it has been due to lack of co-operation amongst the employers, and to the ingrained suspicion of the men with regard to any proposal for the abolition of casual labour.

Many employers view with disfavour any proposal to abolish the large reservoir of under-employed labour, which at present is allowed to accumulate in order to meet the widely fluctuating demands. The dockers also look with suspicion on proposals to reduce casual labour. They think that permanent employment means smaller wages, and reduction of the number of men employed. There is a certain *esprit de corps* which makes men shrink from doing anything which they imagine will throw other men out of work, even if it might possibly be to their own advantage.

The permanent staff of workmen should be well paid and work for a reasonable number of hours. They might be divided into shifts, if found desirable. Such a well-paid permanent staff would be well nourished, and capable of a reasonable amount of overtime in cases of emergency. Now, with such an effective staff, supplemented and equipped with appliances for handling raw material and merchandise, we have a most elastic and efficient combination. By this means we shall move towards Mr. Harold Cox's ideal: "And by a more extended use of machinery and a more scientific use of human muscles, we can secure on the one hand a greater output of work with a diminished cost of production; and on the other, higher wages for the worker with less physical exertion. Those are the ideals for the industrial development of the future. At present their realisation is obstructed by class suspicion resulting in class warfare."

It has been estimated that on the average about 30,000 men daily seek for work at the docks and wharves of the Port of London, and that about 20,000 men obtain it. In other words, 10,000 men on an average seek for work and do not find it. We may safely conclude that similar conditions are met with in other large ports. It is the fluctuating demand for dock labour that has led to the high rate of wages demanded by the men, and to the bitter strikes with which some of us are familiar. It is the high rate paid to the casual labourer which lures men to the docks, and is constantly filling up the ranks of the under-employed. They overlook the fact that the high hour-rate is only paid for the actual time worked, and they do not take into account the hours of waiting and of unemployment for which no payment is received. Casual labour has been described as a subtle form of sweating.

Engineers know that, even when idle, machinery requires watchful care, yet when the complex human machine is out of work, it is often allowed to remain neglected and uncared for. It will probably be said that our poor law relief is intended to meet such difficulties; that the Education (Provision of Meals) Act, 1906, was specially passed to guard the children from the evil effects of their parents' under-employment. Is it not our experience that these costly methods of relief scarcely touch the problems of poverty to which we have referred?

You may naturally ask, What has led me to introduce such social problems as "The James Forrest Lecture"? My answer is, "Nothing but a sense of the gravity of the issues involved." We have by the continuance of casual labour in our docks maintained an army of under-employed, under-clothed, under-fed, and badly housed men, with their dependent families. We have thereby fomented discontent, and trained up a population demoralised by poverty, poor-law relief, and so-called charity, and constituting, in my opinion, a national danger. During the last few years we have in Dublin been face to face with labour trouble. Larkinism has been a familiar phrase. The employers and the employed have been in a chronic state of war. The Citizen Army, organised as an armed force from the membership of the Irish Transport Union, has been a standing menace, and the Government looked on it with apathy and indifference. When the Irish rebellion of 1916 broke out in Dublin on Easter Monday, James Connolly, the leader of the Irish Transport Union, and the successor of James Larkin, supported by the Citizen Army, was the driving force of the outbreak. I have no doubt in my mind that causes which lead men to combine in the manner in which the members of the Irish Transport Union combined are a danger to the State. Those causes in Dublin were the casual labour of our dockers, with its accompanying poverty and miserable housing.

My desire is that we as engineers may be able to assist in finding a solution of this pressing problem of casual labour. The development of appliances for handling raw materials and merchandise must, I believe, prove a potent factor to this end, bringing increased permanent work, increased pay, shorter hours, and better homes to the labourers in our ports. My experience shows that the position of an engineer frequently affords opportunities for influencing both employers and employed, and of mitigating the suspicion so frequently existing between them. For this reason there would appear to be reasonable hope that our influence may be helpful in promoting the use of appliances for handling raw materials and merchandise. If this end is attained, we shall, I believe, further the objects for which this Institution was founded, as defined in our charter, by directing the great sources of power in Nature for the use and convenience of man.

REFRACTORY MATERIALS.

DISCUSSION BY THE FARADAY SOCIETY.

(*Continued from page 379*).

THE TEXTURE OF FIREBRICKS.

BY DR. J. W. MELLOR.

THE requirements from firebricks varies so widely in different furnaces, or in particular parts of the same furnace, that the ideal brickwork can be defined only in abstract terms, and this the more because some properties of firebricks are antagonistic in the sense that some characteristics could be highly developed only at the expense of others. For example, resistance to crushing strains and resistance to abrupt changes of temperature are antagonistic in that the one can only be accentuated at the expense of the other. Texture is one of the most important qualities of a firebrick, since, assuming that the chemical composition and refractoriness are otherwise satisfactory, the life and character of the firebrick are largely determined by its texture. The texture of a refractory may vary from that of the light porous bodies used in making bricks for insulating boilers, &c., to non-porous or vitreous bodies used in making crucibles, acid-resisting bricks for acid towers, &c., with quite a number of intermediate types. It will be most profitable to review a few broad principles in order that the importance of the variations in the texture of firebricks can be understood.

The more important mineral constituents of clays are the granular felspathic or micaceous fluxes, granules of clay

proper, and quartz grains. Virtually all fire clays may be considered to have been made by Nature by mixing these three components with often deleterious impurities: schorl, pyrites, siderite, &c. The osmose process of clay purification is one means of removing these impurities from clays, but before proceeding to that elaboration, slipping and lawning the weathered clay should be tried. The latter can be made to do much of the work claimed as the peculiar merit of the osmose process. Either process of preparation considerably improves most fire clays, but of course it runs up the cost.

When the clay is burnt in the kilns, the fluxes begin to melt at about 900° or 1,000°, and to attack the surfaces of the clays and quartz grains. At a still higher temperature the granules of clay and quartz in contact also begin to react, so that clay is a high temperature flux for quartz (or silica), and quartz (or silica) is a high temperature flux for clay. With silica and ganister bricks, either clay or lime, or both, are the fluxes. The fluxing action, of course, is necessary to bind the brick into a compact whole, to give it a high crushing and tensile strength, and the power of resisting abrasion and attack by flue dust, slags, &c. This fluxing or vitrification is a time reaction—it is relatively slow at low temperatures and fast at high temperatures; a long protracted fire at a low temperature can produce virtually the same contraction as a shorter fire at a higher temperature.

Size of Grain.—There is an enormous increase in the number of granules in a given mass of clay as the dimensions of the particles are reduced. If the grains of a clay were all a millimetre in diameter there would be about 720 grains per gram, and if the grains were 0·0001 mm. in diameter, the number would increase to 720,000,000,000,000 grains per gram. Of course, clay grains are not spherical, and they are not all the same size, but the hypothetical case will best illustrate the meaning. Similar remarks apply also to the increase in the surface of the particles. Reducing the diameter of the grains from 1 to 0·0001 mm. diam. raises their total surface area from 22·6 sq. cm. to 226·415 sq. cm. Consequently, if the vitrification of a clay is the result of a reaction between the surfaces of contact of the granules, the speed of vitrification must be increased when the area of the surfaces in contact with one another is augmented. This is in agreement with some observations made some years ago. Observations have further showed that with clays of approximately the same grain size, the softening temperature is reduced by pressure in accord with the exponential law—

$$\text{Squatting temperature} = Ce - kP,$$

where C denotes the squatting temperature of the clay under no load, P denotes the pressure in lbs. per square inch, and k is a constant of the order 0·001, but which has in general smaller values for silicious than for aluminous clays. Anything which favours the vitrification of a clay reduces its refractoriness or fire-resisting qualities. Consequently, other things being equal, the coarser the grain of a clay the higher its softening temperature, and the coarser the texture, the more refractory the brick. Firebricks made with some clays, with or without fine-grained silica, break down at temperatures which they withstand when made from the same clay mixed with coarse-grained quartz. The quartz grains should be angular, and not in the form of rounded pebbles. There is another important point to remember. When clays are heated on a gradually rising temperature the surfaces of the more fusible granules melt first. Hence again a fine-grained clay with its augmented internal surface will vitrify faster and at a lower temperature than a coarser-grained clay of the same composition. There is therefore a cumulative action in favour of coarse-grainedness for highly refractory bricks.

After-contraction and After-expansion.—The changes which occur during the firing of refractory materials belong to a class which may be termed *arrested reactions*. In these the chemical or physical changes are arrested at particular and definite stages before they are completed. When firebricks are burned or fired in the kilns, the fluxes melt and dissolve, the less fusible materials binding the whole more or less firmly together. A certain amount of contraction occurs during this operation, and if not completed during the firing of the brick it will subsequently continue when the brick is in use. If the after-contraction is considerable, the masonry of the furnace will most certainly be displaced when the bricks are in use. The after-contraction should be small, certainly less than 1 per cent. The contraction test of the gas engineer's specification was an attempt to deal with the after-contraction of firebricks. As soon as the manufacturers realised what the consumer wanted, they gained control of the difficulty, and the after-contraction of commercial samples was reduced from about 1 to about ½ per cent. It is usually impracticable to eliminate all the after-contraction when the firebrick is originally burned, but the object of the manufacturer is to make it negligibly small. The contraction test devised by gas engineers is one of the most useful tests, since it generally makes the weakness of poor bricks apparent by mere inspection. It could be made a little more severe.

With silica firebricks there is usually an *after-expansion*, not contraction. This is due to the gradual change of quartzose silica with a specific gravity 2·65 to another kind of silica with a specific gravity 2·3. The change thus involves a 16 per cent. expansion; it is a slow reaction and usually progresses a little each time the brick is fired. When the clays are heated the quartz expands in a similar manner, unless it be dissolved by the fluxes. The fluxes in a clay also expand about 6 per cent. in firing, so that the normal contraction of a firebrick is the resultant effect of an expansion of the quartz and fluxes, and about a 4 per cent. contraction which clay normally undergoes when fired, whereby its specific gravity changes from 2·6 to 2·7; the particles are also pulled closer together by the surface tension of the molten fluxes. With silica bricks the resultant effect is an expansion.

Grog.—The action of grog in firebricks is rather complex. Grog may be regarded as burnt fire clay (or ground fire brick), which is mixed with the fire clay to serve as a skeleton to facilitate the drying, to control the contraction during the drying and firing of the clay, and also to modify the behaviour of the refractory material when in use. When grog is made by burning the fire clay from which the bricks are manufactured, the main difference between the grog and the rest of the brick is that the grog has been fired twice and the remainder of the brick once. The grog then behaves as an independent constituent. The difference in the nature of the grog and the rest of the brick, however, becomes less and less every time the brick is afterwards fired, unless the grog has been prepared at a much higher temperature than the brick is afterwards fired, or the grog is made from firebricks which have been in use for some time. It will be useful to indicate a danger which is sometimes ignored. Great care may be taken in the grading of the grog (or the non-plastic material) added to a fire clay, but the clay and grog may be afterwards mixed on a revolving plan with heavy rollers, which reduce the size of the grog. The grinding of the mixture of clay and grog under such conditions undoes the careful work involved in the grading of the grog.

The refractoriness of a clay can be augmented still more by fortifying it with some of the higher refractories, shrunk bauxite, shrunk zirconia, carborundum, and the like, but it is not always advisable to make firebricks satisfy the condition for maximum refractoriness at the expense of other properties. The crushing strength and tenacity of a coarse-grained refractory material are low; it is very friable, and liable to disintegrate with shocks, abrasion, &c. Coarse-grained bricks are also readily penetrated by flue dusts and slags.

Machine v. Hand-made Firebricks.—There is often a strong prejudice against machine-made firebricks, but the subject is one which wants careful re-examination. The prejudice is probably the result of an unfair comparison. There are several converging lines of evidence which show that the essential difference was not machinery versus hand, but rather depended on the difference in the time the clay was allowed to stand in contact with water. There is also a tendency for the machine-made body to be less uniform in texture. Pugmills are not really good mixers. The preparation of the clay for hand and machine working usually differs in a way which materially affects its working properties and texture. If the texture of the brick be not uniform, strains will set up when the brick is being heated, owing to a difference in the rates of expansion of the different parts. This will lead to the formation of fissures and cracks, and, maybe, also to spalling. In the dry or semi-dry processes of machine-making, films of air between the granules prevent their packing together so well as in bricks made by plastic processes, and this again has a tendency to make machine-made bricks less sound than hand-made bricks.

Chemical Analysis.—It will be obvious that the chemical

analysis gives no information about the grain or texture of a clay. As a result, the empirical methods of Bischof, Seger, and Ludwig for estimating the refractoriness of a clay from the chemical analysis must all fail in particular cases. No satisfactory substitute for an actual determination of the refractoriness has yet been known. In the case of a composite brick taken en masse, that is, one fortified with quartz, carborundum, zirconia, bauxite, &c., the ideal thing is to tell the consumer the approximate proportion and character of the fortifying agent and of the binding clay. Given the chemical composition of a brick, expressed in this form, it is possible to say whether it is likely to be chemically affected under the conditions which prevail in any given furnace. If the clay itself is coarse-grained, it should be separated into two or three fractions, by levigation, and the chemical character of each portion determined by analysis.

Coarse-grained Firebricks.—Coarse-grained firebricks usually resist sudden changes of temperature better than those of a closer texture. The rule is not without exceptions, but the tendency to split with abrupt changes of temperature can to a certain extent be controlled by keeping the texture of the firebrick open and coarse-grained. Silica bricks are particularly liable to this fault whether they be fine or coarse-grained. In the first fire, the fluxing lime becomes saturated with silica, and the mixture sets; if the set of the grains be afterwards forcibly displaced by internal expansions, the binding agent is materially weakened by the disturbance. A high temperature pre-calcination of all or part of the silica would mitigate the difficulty arising from this particular cause. This is done by some manufacturers. Silica bricks made with pre-calcined material do not always "ring" so clearly when struck together.

Fine-grained Firebricks.—Other things being equal, a fine-grained texture gives firebricks the property of resisting abrasion and attack of fluxes, slags, flue dust, salt vapours, &c. Chemical composition here plays an important part; acidic bricks resist acidic fluxes and basic bricks resist basic fluxes, but basic bricks are rapidly eroded by acidic fluxes and basic fluxes rapidly erode acidic bricks. Texture is also of vital importance. The joints separating the bricks from one another are the weakest places. Here the slag may cut its way until the brick itself is undermined and isolated. Ultimately the brick leaves the setting, rises, and floats on the surface of the slag. Naturally, the use of large bricks would lessen the number of joints, but if the slabs be too large they are particularly liable to crack, and a crack may cause more damage than quite a number of joints. The jointing clay should also be chosen so that it quickly vitrifies without cracking and welds the bricks together when the furnace is fired for the first time.

Applications.—The consumer has to carefully consider the conditions which prevail in different parts of any particular furnace before he selects for trial particular types of firebrick as likely to suit particular parts of his furnace. The bricks near the top of the furnace are not exposed to high temperatures, but there they have to withstand a certain amount of abrasion, impact, and change of temperature. The bricks are liable to spalling and disintegration due, as is supposed, to the deposition of carbon formed by reactions between the iron oxide in the brick and the furnace gases. Nodules or patches of iron oxide in the bricks are more liable to serious trouble than is the case when the iron oxide is more uniformly diffused throughout the mass. The bricks should also be close and compact. The temperature conditions become increasingly severe in descending the furnace. The upper parts of the lining are normally protected to some extent by the development of a surface film of carbon, but the friction of the descending charge and the impact of fine particles of solid carried forward by the blast may produce erosion, particularly if concentrated in local parts. The bricks in the mid-zone are also exposed to the slagging effects of particles of salt and other basic fluxes from the coke. There are no very abrupt temperature changes, so that a close-textured compact brick is desirable for this region. The conditions which prevail in the hearth and bosh require a very special brick to withstand high temperature, to resist the scouring action of highly basic molten slag, and a rather heavy mechanical load; the volume changes should be small, since the bricks must be tight without leakage; but there is comparatively little wear and tear by abrasion. The stove bricks should have a high thermal capacity, so that they can absorb and give up the largest possible amounts of heat and be capable of resisting the sand-blasting action of flue dust.

DISCUSSION.

Dr. Lessing referred to some tests which he had made five or six years ago for the elucidation of the composition of unfired mixtures, especially in relation to the manufacture of gas retorts, because it was most difficult once a brick had been fired to distinguish chemically or otherwise between the components of the very complicated composite mixture which then existed. The results of these tests demonstrated the need for the adoption of a standard specification on the lines of that prepared by the Joint Refractory Materials Committee of the Institution of Gas Engineers and the Society of British Gas Industries.

Dr. H. G. Colman outlined the work of the Joint Refractory Materials Committee of the Institution of Gas Engineers and the Society of British Gas Industries. The main work of the Committee has been the drawing up of a standard specification for the various classes of materials commonly employed in gasworks, and the carrying out of research work. As far as the latter was concerned, the Committee had not been able to proceed as it would have wished, as the available funds, even with a grant from the Privy Council, only amounted to £230 per annum. A much larger sum was required, and he appealed to all interests to co-operate to this end. The chief matter on which research had been in progress recently had been that of the influence of pressure on the refractoriness of a firebrick, this being a matter of great importance both for gas retorts and coke ovens. Investigations under six further heads were in progress under the direction of Dr. Mellor, including the determination of the difference in size of bricks when cold and when at high temperature, the cement material employed, the relative effect of an oxidising atmosphere and a reducing atmosphere, and the effect of firing temperatures on the subsequent refractory qualities of the goods.

Mr. J. Allen Howe, speaking on the recent work of the Geological Survey on refractory materials, said that when war broke out there arose a demand for information as to the supply of various minerals in Great Britain, and as a result of this Dr. Strahan (Director of the Geological Survey) had produced a number of special reports of the mineral resources of Great Britain, and the next of these would deal with refractory materials. In preparing this report the Survey had got together samples of the raw materials, together with exact information as to the locality whence they were obtained, the geological characters and the extent of the deposits, and the special local circumstances attending the extraction. In carrying out the field work involved the plan adopted had been to tackle one by one the principal areas of refractory material production, to visit each of the quarries or mines and consult the producers of the raw stuff and makers of refractory ware. One field party started operations in the Sheffield district, and worked northward to Durham and Northumberland, whilst another began in the Stalybridge district, passing then through the Midlands towards North Wales, Lancashire and Cumberland; another party dealt with Scotland, and South Wales was just being finished. Several isolated areas had to be dealt with separately. At the same time it was considered expedient to visit in each of the mine centres a few of the principal users of the material, and the first consultation of this kind took place at the works of Sir Robert Hadfield. Since then a number of the leading steel works had been visited as well as iron, copper, and spelter works. The object was to produce in one or two handy volumes an account of the raw refractory materials of Great Britain with information as to their geological position and available resources, their petrological and mineralogical characters, together with strictly comparable data of their chemical and physical properties.

Mr. Crooks (of the Imperial Institute) spoke specially upon the question of the supply of refractory materials in different parts of the Empire. There was no better graphite than the Ceylon graphite, and there were also considerable supplies in Southern India. Similarly there were abundant supplies of it in Canada, and it was of the particular flaky type which was so important for crucible manufacture. Of

the least important varieties of graphite there was a fair amount of the amorphous variety in various parts of South Africa which, although not comparable to some of the Mexican and Korean, which were very much in request, still were very useful materials. South Africa also had supplies of these lower grade forms of graphite. There were also abundant resources of magnesite, which originally came from Syria and Greece as well as Austria. There were the Heathcote deposits in Victoria which had already been worked to a considerable extent, and there were also considerable deposits in the Transvaal and elsewhere. A somewhat singular deposit was in the shape of a hydro-magnesite, very similar to the ordinary magnesite, in British Columbia, and from one deposit 100,000 tons had been obtained already. The high water content was a difficulty, however. India also had considerable supplies of bauxite, and, of course, there were the Antrim deposits in Ireland. In British Guiana, American capitalists were giving close attention to the deposits of bauxite, and there was little doubt that few people realised the immensity of the Empire's resouces of the various refractories.

Mr. Cosmo Johns, speaking generally on the question of silica as a refractory material, mentioned the want of exact knowledge as to the properties of this material, and suggested the necessity for establishing a standard specification after carrying out trials of various sands in the furnace with competent observers and good workmen. Even pure silica must contain some little impurity, and although he had arrived at certain figures regarding this they were merely an approximation, and could not be definitely put forward until much more experimental work had been carried out. As far as his personal knowledge went, there should be about 2 per cent. alumina and certainly not more than 0·5 per cent. of iron oxide. Alkali was always an evil, and should be small in quantity, say not more than 0·15 per cent. Magnesia might also be present, but a sand containing all these constituents must be classed as a bad one. The best sand was the lower green sand from Leighton Buzzard, and he believed similar sand existed near the Wash and no doubt elsewhere. One fact which showed that the steelmaker at any rate was not always so backward in science as was sometimes suggested, was that when war broke out the supply of sand for open-hearth furnaces was cut off, it having been up to that time almost exclusively Belgian silver sand, which was admirably suited for the purpose, having a small percentage of alkalies and high quartz. Yet without the slightest fuss British steelmakers had been able to secure supplies of sands in apparently enormous quantities, having regard to the very considerable demands upon their works at the present time.

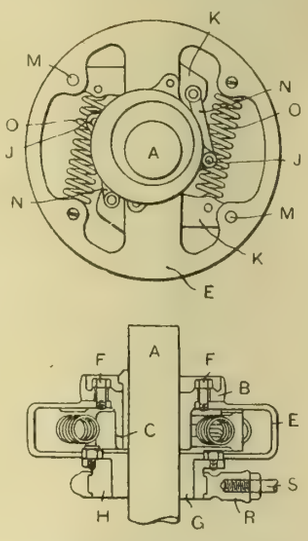
Mr. Jones (of the Steel Production Department of the Ministry of Munitions) urged that the steel industry could well afford to set up some organisation by which the interests concerned could be brought closely together, and by this means the perfect brick would be more quickly produced. He did not think the steel industry had paid sufficient regard to the importance of silica bricks in furnace construction until the war broke out. That was perhaps because the industry was always in a position to get as many silica bricks as it required, but the necessity for largely increasing the output of steel had at very short notice brought home very forcibly to all steelmakers the great part that refractory materials played in connection with furnace construction and incidentally the output of steel. He urged that if Great Britain was to be the great steel-producing country which it could be, and which was necessary if we were to pick up the trade from our enemy, which was the great desideratum, a closer co-ordination between the laboratory, the steelworks, and the refractory materials works was essential.

(*To be continued.*)

Acetylene Committee.—The Home Secretary has appointed a committee to consider the existing regulations in regard to filling, marking, and pressure, &c., of cylinders of dissolved acetylene compressed into a porous substance, and to suggest amendments of these regulations where this appears desirable. The secretary to the committee will be Major Crozier, and all communications should be addressed to him at the Home Office, Whitehall, S.W.

CONTROLLING THE SUPPLY OF FUEL TO OIL ENGINES.

A PATENT recently granted to Mr. E. W. Petter, M.Inst.M.E., of 73, Queen Victoria Street, London, E.C., relates to variable delivery fuel pumps for oil engines, and comprises an arrangement for adjusting the moment of injection of the fuel so as to make it earlier or later as required to suit the working conditions of the engine. An elevation with eccentric strap removed and section of the apparatus is shown in the accompanying cuts. Upon the shaft A is fitted a carrier comprising a pulley B having a sleeve C, the carrier being provided with concentric slots. On the sleeve is disposed a casing E adapted to be adjusted angularly on the carrier, and to be secured in position by the studs and nuts F. Upon the casing E is formed an eccentric G, which bears on the shaft A. On this eccentric is disposed the outer eccentric H, provided with lugs J. On the casing E are mounted weights K, pivoted at M. Links N connect the weights K to the lugs J. The weights are held towards the shaft A by means of springs O, which are attached to the casing and to the weights. Upon the eccentric H is disposed the strap R to which the pump connecting rod S is attached. In operation as the speed increases the weights K fly out and pull the eccentric H around the eccentric on the shaft A, whereby the eccentricity is reduced and consequently the throw of the pump and the amount of fuel supplied to the combustion chamber. In order to alter the moment when the fuel is injected the casing E, and with it the inner eccentric G, is moved in relation to the carrier, which is keyed to the shaft.



DEVICE FOR CONTROLLING THE SUPPLY OF FUEL TO OIL ENGINES.

THE INSTITUTION OF CIVIL ENGINEERS.

PRESIDENTIAL ADDRESS.*

(*Continued from page 386.*)

THERE is another class of work on which I have seen a good deal of time and money lost, namely, the drainage of low-lying bog lands. I remember one case of a large low-lying area near a river, and surrounded by higher bog land, where drainage operations were undertaken on a large scale, and where what might be mistaken for canals were cut through the area. After some years these canals disappeared, and the bog returned to its natural state. Whether such failure was due to the drains so disturbing the equilibrium of the surrounding country as to cause bog-slides, I do not know. It is possible that a larger number of smaller drains might have been successful; or that if the larger drains had only been gradually deepened over a long period, allowing the ground a chance of consolidating, a more satisfactory result might have been attained. I made no investigation of the matter, but after knowing what happened, one can wisely say it would have been well to make an experiment on a much smaller scale to begin with.

Some time ago my attention was drawn to the fact that it had been necessary, after some 10 years, to renew a long length of heavy hardwood wharf owing to ravages of teredo. Just above the wharf, and apparently under the same conditions, the piers of a bridge, constructed of the same kind of timber, and which had been built 40 years previously, appeared to be quite sound. This was a case where the engineer who constructed the wharf commenced the work after full investigation, and where the probability of a long life for the wharf was, one would imagine, almost certain. I was not at the time given any definite

* Delivered by Sir Maurice Fitzmaurice, C.M.G., M.A., M.A.I., LL.D., November 7th, 1916.

reason for the difference in the life of the timber at the two places. I was not able to investigate it, and I am doubtful whether any investigation at that time would have disclosed a satisfactory explanation.

Even in steel bridge work we have not as much knowledge about the actual stresses which occur as is generally supposed. The actual effect of rolling load on bridges has been considered here recently. I do not think it increased our knowledge very much and there certainly was considerable difference of opinion. In the different members of very large bridges questions arise on which engineers have come to a decision, but such questions as initial stresses in materials, secondary stresses due to distortion, and sometimes the varying stresses due to erection, are very difficult to tackle with any confidence of arriving at exact results.

A cause of occasional failure in temporary works is due to the fact that engineers and contractors sometimes take deliberate and justifiable risks in connection with such works. If I may again refer to the Assouan Dam, it will give an example of a case where risk was deliberately taken in connection with some temporary works, and where failure resulted. In the construction of this work it was necessary to close the deep summer channels of the Nile by temporary dams of stone and sand. The time required for the construction of these temporary dams was considerable, and the time between one Nile flood and the succeeding one had to be used to the utmost advantage to get in the foundation for the permanent work and to raise the masonry above flood level. It would have given considerably more working time for the permanent work if it had been possible to construct one of the temporary stone dams previous to the Nile flood. There was, however, the question whether such a temporary dam would survive the Nile flood, and the contractor decided to take the risk. As a matter of fact, the temporary dam was swept away at an early stage of the flood. The comparatively small cost of the temporary dam, some £10,000, when compared with the great advantage which would have accrued in the following working season if it had been successful, certainly justified the risk taken.

In many cases of temporary works where risks are taken deliberately, the cost of reconstructing such temporary works, should failure occur, might only be a small portion of the cost involved if the works were constructed in a more solid manner and in such cases the risk is fully justified.

Perhaps I have said enough in this rather melancholy recital of some of the difficulties which engineers have to contend with to show that the common saying that engineering is not an exact science hardly goes far enough to show how inexact a science it is. Although much of the work of an engineer is based on strictly scientific procedure, it is to a great extent dependent on experiment, experience, and a proper appreciation and balancing of the inexact knowledge available.

It is under these circumstances hardly to be wondered at that estimates of cost and time of construction are not always accurate. Although it is not possible to draw any very close deductions from different tenders submitted by competent contractors for the same work, owing to the fact that one contractor may happen to have in his possession the necessary plant, may have some special facilities in a certain locality, or may have a particular reason for wishing to keep some of his staff together, still the great diversity in the amounts of tenders received from capable and experienced contractors, after making allowance for these matters, is only a very practical confirmation of the fact that exact estimates of time and cost are impossible.

The difficulties I have mentioned, and many others, are, however, the reason why our profession is such an extremely interesting one. New unforeseen difficulties turn up every day, and new methods are being continually found out for dealing with them. Engineering works, after all, have to be carried out, and engineers and contractors have to design and construct them to the best of their ability. It is difficult to make any suggestions to facilitate our work, but it has occurred to me on more than one occasion that our brother engineers on the other side of the Atlantic devote more time than we do to preliminary work and studies, particularly in the case of large undertakings. They appear in some cases to have taught their clients that time and money spent on very full investigation and preliminary studies give a very good return on the expenditure. The Governments of Canada and the United States are also not averse to collecting information about rainfall, river discharges, and other matters, which information is at the disposal of those who wish to avail themselves of it. If we could prevail on our clients and on our Government to take similar views, they would also find that the money was not wasted. We are, however, as things stand, dependent to a great extent on experience and private investigation and experiment for the success of many of our works. We ought not, at the same time, to forget the great obligations which we engineers are frequently under to chemists, geologists, metallurgists, meteorologists, and others, for the great help which they ungrudgingly give us.

I hope, however, that the Government "Scheme for the Organisation and Development of Scientific and Industrial Research," which has recently come into existence and which has already made a grant to this Institution for research work, may be a real help to engineers. The scheme, in its main features, is one conceived on broad and patriotic lines, which may lead to results even greater than were anticipated by those who framed it. As far as I know, the detailed arrangements under which it will be administered have not as yet been definitely laid down. Some, but not all, of the industries which may expect help are at the present time so engaged with war work that it is not possible for those controlling them to consider fully, much less to carry out, useful research work. Such work, to be of real value, must be undertaken in consultation with the different industries. It is, however, important that some definite lines for the working of the Government scheme should be laid down at an early date. I hope and believe that it may be developed on such broad, liberal, and generous lines as will command general confidence. If worked on such lines the scheme will be of great value. "A great empire and little minds go ill together."

I mentioned at the commencement of these remarks the want of success of individuals. It may seem out of place to refer at this time and in this Institution to such a subject, when practically all the members of fighting age are serving either in the Navy or Army, and when all those who have passed that age are lending a hand to the country in some other way. If the willing, and more than willing anxiety to help in what has been called an engineer's war is a measure of individual success, then the members of this Institution have closely attained to it. We know that over 2,000 of our members, out of a total roll of about 9,000, are serving in the fighting forces, and that we have up to date to mourn the loss of nearly 150 members who have made the great sacrifice of their lives.

The time will come, however, when we must settle down again to our every-day duties, and thefore I venture to say a few words on the question of want of success in individuals. All of us, no doubt, on many occasions during our lives have made mistakes which, with a little reflection, we might have avoided. We have often bought our experience dearly. We probably realise that in some cases there was very little margin between success and failure. In looking back, however, over the great number of engineers whom I have come across in works, and in offices, I cannot bring to mind any case of a hard worker who has really failed. It is true that all of them have not arrived at commanding and independent positions, but, then, all men have not the ambition, or wish, or capacity, for such positions. The attainment of such a place might possibly mean failure for some of them, and they prefer to retain the confidence and respect of their employers in the secondary posts, and in doing so they probably have a less anxious and a happier life. I know of some engineers who have not attained to high positions, but who could be sent to take charge of works, with the knowledge that every stage of the work will be carefully and continuously inspected by them, and that if any difficulties arise they will recognise them, and at once report to their chief fully and clearly about them. Such men are invaluable.

There are, however, also a great number of engineers who begin their professional work with the hope and determination of getting to the top rung of the ladder, or at all events making a good fight for it. They realise that the time will come when the seats around this table will be filled by those who are

now the younger members and they want to be there. The roll of this Institution, I am glad to say, is formed of men drawn from all classes of society. I consider that there has been in recent years some improvement in general education which tends to give capable boys the chance of taking up the profession of engineering when they have an inclination in that direction. Very much more, however, might be done in this connection. As far as my knowledge goes, the facilities for the preliminary education of engineers in Canada, Australia, New Zealand, and the United States are in some ways greater than in this country, particularly as regards imparting some very necessary commercial knowledge. I believe, also, that in our elementary schools we aim too much at educating everyone up to one standard; we donot pay sufficient attention to the individual, and there is hardly enough opportunity for the better boy to shake himself free from the average. By such method money is wasted in endeavouring to educate a large proportion of boys up to a standard which they can never attain, and which, if they did attain, they would never profit by.

I did intend to say something more about education in schools to-night, but having read during the last six months the debates on education in both Houses of Parliament, the speeches made at various important meetings, and the voluminous correspondence and articles in different papers and journals on the subject, I do not feel that my experience justifies me in taking up your time. Everyone acknowledges *now* that science has in the past been neglected in education in this country. Everyone, or nearly everyone, agrees *now* that the teaching of science must be one of the principal features of the national education. In the debate in the House of Lords on July 26 last the Marquess of Crewe stated it was the intention of the Government to set up a committee to review generally the whole field of national education, and another small committee to look into the question of scientific teaching. Two committees have so far been appointed, one to consider the teaching of natural science and the other modern languages. I hope there may be some result from the labours of these committees. During the last 12 months committees have sprung up like mushrooms, and it must be getting difficult to find the right men who can give time to them.

Before leaving the subject I may, however, say that I am one of those brought up on compulsory Latin and Greek to the age of 19. Both languages were taught to me in such a way as to develop the minimum amount of interest in my mind with regard to the many instructive books which I read. I think this teaching did me some good and certainly no harm. I have often since thought that I might have received a lot of good from it if these languages had been taught in an interesting way.

On the other hand, I was taught mathematics and such experimental science as was possible at that time by a man whose teaching was alive and who made the commonplace things interesting. In fact, one could not help learning from him. I only mention this because the contrast between the teaching of the two subjects was great, and because I want to draw attention to the fact that whatever educational programme may be devised a great lot depends on the teachers. The live teacher is one of the problems.

While I need hardly say that I am extremely keen about a radical alteration in our teaching so that scientific education may be kept all the time in the foreground, I do not wish to see young men growing up without what in an old-fashioned way would be called a good general education. We at this institution have been altering our examinations and practical requirements from time to time so as to raise the scientific standard required for students and associate members, but we have not forgotten the value of a good general education. I think, however, the time has arrived when a knowledge of one or more modern languages should be made obligatory. I am sure that in the future the institution will not fail to retail its general education requirements, while at the same time helping on scientific training in every possible way.

I have frequently been asked by parents of budding engineers, and by young engineers themselves, for advice, and the remarks which I have to make on this subject are specially directed to the students and the very young members of the institution. The examinations by the institution, or the corresponding ones at the universities, which have now for some time been required before a young engineer can become an associate member of the institution are, of course, only the groundwork for the work to come later on. Nothing can take the place of experience and actual contact with difficulties. It is therefore necessary that an engineer should devote his time to getting all experience possible.

I remember being told many years ago by a friend who had passed through the Engineering School at Cambridge University, that he asked the professor of engineering at that time for some advice on what he should do. The answer he got was: "Try and get into some large shops, or on to some large works; if you can't get taken on as an assistant or improver, try and get taken on as an assistant timekeeper." There is something to be said for that advice.

I have on one or two occasions been asked by a young engineer whether, of two posts offered to him, he should take that of one amongst many assistants on a large work with a small salary, or that of resident engineer on a small unimportant work at a considerably higher salary. Without hesitation I recommended the former position. I knew that on the large works he would see a little of almost every class of work, that even the temporary works of the one were probably more important than the permanent work of the other, and that the fact of being on a large work would be of great assistance later on and would stand to him all his life. He would also have the advantage of daily intercourse with other engineers, and the emulation and friendly rivalry between them would lead to efforts on his part to hold his own. There also exists on large works a feeling which I can only describe as engineering atmosphere, which may have a real influence on the life of a young engineer.

Experience and the passing of hard engineering examinations are, however, not the only requisites for success in our profession. I suppose there is no class of engineer more in request than the resident engineer or assistant engineer with experience who can "get on" with people. Engineers are afraid of assistants who can't get on with people. Such men irritate clients; they cause trouble whether they are on the engineer's or contractor's side. The capacity of getting on with people and still holding one's own has a distinct money value, and a very high one.

Closely akin to it is the one of being fair in dealing with questions which arise on works. The resident engineer and the contractor's engineer who are open with each other, and will not take an unfair advantage of one another, have both obtained a reputation of great value, and which may have a far-reaching effect even on both their firms.

In my opinion there is nothing which so much enlarges a young engineer's breadth of view and gives him a feeling of self-reliance as a few years' work abroad. The ideal conditions in connection with this are that it should be after some years' work at home, and be on works under construction by a British firm; but these ideal conditions are not, of course, always possible. One can only acquire knowledge of how works are carried out abroad, and the differences between such works and those in this country, by actually being engaged on the details of construction. In going abroad, young engineers should be careful, if possible, not to break any engineering connection which may have been formed at home. I personally have always considered it was extremely fortunate that I was employed for seven years on undertakings outside this country. In view of foreign work, it is essential that a young engineer should know well at least one foreign language. This knowledge will often be the deciding factor in gaining an appointment.

(To be continued.)

The Royal Society.—The Council has awarded the Copley Medal to Sir James Dewar, F.R.S., for his researches on the liquefaction of gases; the Rumford Medal to Prof. W. H. Bragg, F.R.S., for his researches in X-ray radiation; the Davy Medal to Prof. H. L. le Chatelier for his researches in chemistry; and the Hughes Medal to Prof. Elihu Thomson for his researches in experimental electricity. The Council recommends that Sir J. J. Thomson be elected president at the anniversary meeting on November 30th.

EFFICIENCY OF PROPULSIVE MACHINERY AND LATE DEVELOPMENTS IN NAVAL ENGINEERING.*

BY LIEUT.-COMMANDER H. C. DINGER, U.S.N.

(*Concluded from page 389.*)

Steam Used by Auxiliaries.—A number of tests have recently been made to determine the percentage of total steam used by the auxiliaries of naval vessels, and following are given the approximate values obtained from averaging these results :—

Capital vessels—					
Speed, knots	10	15	19	21	—
Per cent. of total steam	38	30	18	14	—
Destroyers—					
Speed, knots	12	16	20	25	30
Per cent. of total steam	27	21	17	13·5	12

It will be noticed that the percentage of steam used by the auxiliaries in the case of the destroyers is considerably less than that used by the large vessels. This condition accounts for the fact that the destroyer machinery proves to be more efficient than that of the capital vessels. The above are average results for certain average conditions, but it is believed that the steam consumption of the auxiliaries can, by special care and attention, be reduced from 10 to 25 per cent. below the average conditions which obtained when the water consumption was measured.

The auxiliary exhaust that is not used in the feed heaters is used in the low-pressure turbines, so that under the conditions of actual operation the auxiliaries do not use the full extent of this percentage, and all over about 10 per cent. is used in the low-pressure turbine, where it will give approximately half the return that the same amount of live steam entering at the throttle would give. Therefore, strictly speaking, the auxiliaries, except electric generators, should be charged with only about half of the above percentages, since they exhaust at about 10lbs. pressure, and this exhaust is used effectively both in the feed heater and in the turbines. The following table has been compiled to show the approximate steam consumption of various auxiliaries on large vessels for full-power conditions. The amounts of steam used are quite variable and depend not only upon the design of the auxiliaries but also on the method of operation. The following gives the percentages of steam used by the auxiliaries :—

	Per cent. of total steam.
Feed pumps	3·0 to 5·0
Circulating pumps	1·5 to 2·5
Air pumps and condensate pumps	0·2 to 0·6
Forced-draught blowers	1·5 to 3·0
Lubricating pumps	0·1 to 0·2
Oil-fuel pumps	0·2 to 0·4
Total for auxiliary machinery necessary to operate main engines	6·5 to 11·7
Bilge pumps, ice machines, steering engine, and other miscellaneous machinery	1·0 to 4·0
Dynamo plant other than forced-draught blowers	1·0 to 2·0
Total	8·5 to 17·7

Evaporating plant, depending on rate of use.

The principal steam users among the auxiliaries are the feed pumps, circulating pumps, and forced-draught blowers; the other auxiliaries of naval vessels use a relatively very small percentage of steam. The introduction of turbine-driven centrifugal feed pumps will reduce the steam consumption for feeding. The consumption of circulating pumps is reduced by the use of scoop injection for condensers on destroyers and scouts, and on other vessels where this is practicable. The consumption for forced-draught blowers is reduced by using larger blower units and by having arrangements made whereby two blower units are compounded. Compounding has actually been made use of in several instances.

Electric forced-draught blowers have been used on a considerable number of large vessels. While this practice is fairly economical, the desired speed regulation is not secured, and electrically-driven blowers are not well suited to oil-burning installations. The objections to the electrically-driven blowers are : (1) Difficulty in obtaining as variable a speed as is desirable and necessary with oil fuel. With steam turbine drive minute regulation is possible. (2) Additional generating units have to be started when a considerable number of blowers are started (3) Starting and stopping of blowers creates a very variable load, and in order to accommodate this load extra generators have to be kept in operation. (4) Electrically-driven blowers cannot be efficiently operated at low speeds, and in many cases a low speed is desirable to suit the boiler output at any one time. (5) Circuit breakers are likely to blow, and if this happens flare-backs may take place and all steam generation be stopped until the blowers are again started. With steam-turbine drive it is very unlikely that all blowers would stop at the same time.

It must be remembered that the auxiliary exhaust is now invariably used for feed heating and in some instances for distilling, so that the actual heat used by the auxiliaries is really from 4·5 to 9 per cent. of the total instead of from 8·5 to 18 per cent. The auxiliaries can, by lack of care in design, condition, and operation, become very wasteful, so that they do, in cases, use two or three times the amounts stated. But in our best performances we are reducing the percentage of available heat used by the auxiliaries to approximately 5 per cent. of the total at full power. By improvement in design and operation this figure can be still further reduced, but no very marked further saving in steam used for auxiliaries is practicable.

New Types of Machinery.—In the search for economy and efficiency there are new types of naval machinery to deal with which are causing both the directly connected turbine and the reciprocating engine to be superseded. These are the geared turbine and electric drive. The hydraulic transmitter has also been considered abroad. These innovations, which have actually been tried in quite a number of cases both on naval vessels and in the merchant marine, will secure an advantage in economy of 10 to 15 per cent. as compared with the directly connected units, as well as a material saving in weight. In this connection note the position of the curves of the "Wadsworth," our first U.S. geared destroyer. For certain types of vessels the geared turbine has the advantage over the electric drive. For other types the reverse is the case.

For large capital vessels of high speed the electric drive appears to have the advantage for the following reasons : (1) There is much more flexibility so far as arrangement and shaft and piping connections are concerned. (2) Better economy at cruising ranges is secured. (3) Generator rooms, boilers, piping, &c., can be more adaptably arranged. The necessity for bringing large steam pipes through boiler compartments and back to the engine room is avoided, electric conductors taking the place of these large pipes. (4) Parts of machinery can be undergoing repair while other parts are in operation at a very large percentage of the total power of the vessel. (5) Much better handling conditions are secured, and a greatly improved power for backing is present without the complication caused by the use of backing turbines. (6) It is entirely practicable to use a high degree of superheat.

Gearing versus Electric Drive.—Gearing is more suitable than the electric drive for light, high-powered vessels of the destroyer or scout type, because it is more compact and, within the limitations of these vessels, is lighter than the electric drive. It is a little more economical at high power, but not as economical at cruising and intermediate speeds. Gearing is more suitable for light, high-powered installations where weight and space are cut to the minimum and where the power is not so great but what the leads of steam piping and shafting can be satisfactorily handled. The turbine-reduction-gear lay-out does not permit of as much protection to the machinery, and the handling arrangements and flexibility are not as good. In the scout and destroyer designs, machinery of the following characteristics may be applied : Powers up to 25,000 shaft horse-power on one reduction gear set, two pinions being utilised. Water consumption of 10·5lbs. to 11lbs. per shaft horse-power at full power ; machinery weight (total) about 40lbs. per shaft horse-power. Such machinery contemplates the use of scoop injection condensers, and also the possible use of steam ejectors or kinetic tanks in place of air pumps. Such machinery also requires the reduction of all the auxiliaries to the lowest limit that is practicable.

A comparison of gearing and electric drive on various points is given below. The advantage is not all one way, and the special

*Paper presented at a meeting of the Philadelphia section of the American Society of Mechanical Engineers, May 23rd, 1916.

conditions of vessel and her service requirements will govern the choice of one type or the other.

GEARING.	ELECTRIC DRIVE.
Weight.	
The initial advantage rests with the gearing, since the gear will not weigh as much as the generator and motor combined. As very large powers are used and a multiplicity of shafts, this advantage is lessened.	The saving of weight by using gearing will, however, not be a very large percentage of the total machinery weight, probably not more than 1 or 2 per cent. However, considerable weight in piping is saved by means of the electric drive, so that for large vessels the weight of machinery is about the same for either gearing or for electric drive.
Space.	
The advantage will rest to a slight extent with gearing, so far as the cubical contents are concerned.	The space can, however, be in many cases more advantageously utilised. The generator can be placed at some distance from the motor. The shaft can be greatly shortened. This advantage shows up specially on large vessels. Superior boiler-room arrangements can be utilised.
Racing.	
The gear and turbine will be subject to the racing action of the propeller.	There will be no racing. The motor will govern the propeller and maintain even speed. This fact may possibly produce a slight gain in propulsive efficiency.
Handling.	
Handling is satisfactory.	The advantage rests with the electric drive, especially with regard to backing power. See Jour. A.S.N.E., February, 1916, Stopping, Backing, and Turning Ships, by Lieut. S. M. Robinson, U.S.N.
Adaptability to Best Conditions for Efficient Propulsion.	
The gear ratio having been adopted it cannot be changed. If the effective horse-power and propeller efficiency have not been accurately estimated, an improper ratio will be present which may prevent the turbine from securing its most efficient speed. Unless very high gear ratios are employed the most economical turbines cannot be used.	The relative speed of propeller and turbine can be altered to any extent. The turbine can therefore run at its most efficient speed without reference to the propeller speed. This enables a very high speed turbine to be used, which allows of greater economy. The design can utilise the very best propeller conditions without affecting the design or limitation of the turbine.
Facility for Repair.	
No special advantage. Whole engine plant has to be run when under way. At present large gears can only be cut by very few firms.	In case of accident generator and motor parts can be renewed more easily than gear can be repaired. One generator can be repaired while other works to full power. This will give about three-quarter-speed.
Repairs to be Expected.	
Repairs to gearing will be little or nothing; but if damaged to any extent, however, gear will have to be replaced. A spare gear should be at hand to replace one damaged by accident.	The repairs to a generator and motor may be of considerably greater extent and may cost more than those to gear, but they can be more readily made, and actual experience with the "Jupiter" does not indicate that there will be large repair bills.
Economy.	
With the same boilers and turbines gearing has an advantage of about 5 per cent. at full power. The same turbines may, however, not be feasible, since the turbine to be used must accommodate itself to the gear that is being used.	Owing to ability to use only one generator at below half power the ability to run generator at practically constant speed and the flexibility of the electric bond to adjust itself to any speed ratio, it is likely that the initial advantage of gearing in economy will disappear at cruising speeds, and at low speeds the electric drive will be more economical.
Reversibility—Backing Power.	
Requires a backing turbine, which complicates design and enables only a portion of full power to be used for backing. Limited to about 50 per cent. backing power, even with very large backing turbines.	Full backing power is secured without disturbing turbine. Reversing is made particularly easy, and the full utilisation of the steam supply is possible for backing, since there is about the same engine efficiency backing as going ahead.
Care in Operation.	
Little or no special care required for the gear. Oil supply the essential matter. Some difficulty in lubrication has been experienced.	Considerable attention will have to be given to maintaining generator and motor in condition. This also requires a special knowledge of electrical features, for which personnel will have to be specially trained. Ventilation of motor and keeping it dry will require special attention.
Facility for Installation.	
Location of turbines and gear fixed by position of shaft.	Generators can be located anywhere without regard to shaft. Best location of condenser, steam piping, &c., can be secured. This enables a more adaptable and simple arrangement to be made. Special advantage of this may be taken in making best provision for torpedo protection.
Certainty of Data on Which to Base Design.	
Gears suitable for very large power have not yet been built in this country. Each installation practically necessitates a new design of the gear. Existing installations have been generally successful, but some trouble with wear on gear and breaking of gears has been experienced.	All portions of the electric drive apparatus have been built and fully tested out. They have been applied to onemarine instalation and have been successful.

The Ljungström turbo-dynamos are a new feature in marine electric driving, but though there has been an installation actually built, the device is still experimental. If it stands up in service, it will be a means of improving the now accepted type of electric drive in this country by about 10 per cent. Nothing definite has been done with this device in the United States, though a great increase in economy is claimed for it and has been secured in numerous actual installations.

Boiler Efficiency.—The campaign for economy also makes it necessary to enquire into possible ways of improving boiler economy. Boiler efficiency has remained approximately at a standstill for quite a number of years, but the advent of oil burning has given a new phase to the situation. By means of improved burners continual improvement in combustion has been effected. A great deal of experimental work has been done by the fuel-oil testing plant at the Navy Yard, Philadelphia, and marked improvement in burners has been secured.

It is believed, however, that we are about to secure a material

improvement by arranging the heating surface of boilers so as to secure a proper relation between the flow of gases and the circulation of water. The actual course of circulation in water-tube boilers is a matter that bears study and investigation. A recent disclosure has shown that some generally accepted ideas are in error. It is believed that to obtain the best efficiency the gases must be so directed as to pass in the counter direction to the flow of water in the tubes, and that as the gases are cooled and the volume reduced the area of the gas passage should be decreased in order that the velocity of the gases may be maintained at a proper point for the requisite efficiency. Some experiments along these lines are under way.

The best boiler results that we have record of give from 77 to 81 per cent. efficiency for well-baffled straight-tube boilers (with 0·1lb. to 0·3lbs. oil per square foot of heating surface), and about 70 to 78 per cent. for express boilers. With coal the boiler efficiency averages about 5 per cent. less. It is believed that by special care based on proper experimental data a boiler efficiency of 85 per cent. can be secured for continuous operation on board ship, this economy to be effected by means of proper baffling and proper relation of baffling to boiler circulation, and by supplying more efficient clothing and lagging. An oil furnace means a higher furnace temperature, and hence more boiler clothing is needed.

Special Conditions of Design.—The demands upon the engineer to secure in the new designs the necessary power for a great increase in speed, as well as for special and unprecedented protection from torpedo attack, have made it necessary to get every bit of power out of every pound of weight and cubic foot of space allowed. Everything non-essential must be left off, and every part must be designed to be adequate but without excessive margin. The principal method of saving both weight and space is to install machinery that will secure the highest practical economy, and in searching for the means of accomplishing this the naval engineer is looking to the engineering talent of the country to come to his assistance.

New Developments in Naval Engineering.—The present time is especially a period of development in naval engineering. The European war, and the developments caused by it, have emphasized, and will tend to emphasize, many new features and point out special lines of advancement in naval engineering. We are now almost at the stage of discarding the reciprocating engine and the direct turbine drive for new fighting craft, and in their place are coming turbine reduction gear and the electric drive, with the oil engine for submarines and as a possibility for some auxiliary vessels. Coal burning is being superseded by oil burning on nearly all classes of vessels building for our navy. There have been recently successfully tried three super-dreadnoughts, the "Nevada," "Oklahoma," and "Pennsylvania," all of them equipped with oil-burning boilers exclusively. This marks a special step of progress in the evolution of naval engineering work, and the use of oil fuel has permitted many engineering and operating advantages to be secured. Special development is taking place in the field of aeronautical apparatus, and a great deal of this is being done by the co-operation between the navy and the engineering industries of the country. Many new developments of condensing apparatus, pumps, and other auxiliaries are coming on. New things are dawning all the time, and as fast as they give promise of practicability, reliability, and proper adaptation to naval use, they are tried out and adopted. There is continual progress towards greater efficiency, greater economy, compactness, and in reduction of weight, which enables the United States to take the lead in engineering development. Such developments are largely the result of co-operation between the industrial engineers and the naval engineers. Further to develop this, more experimental and laboratory work is necessary, and the country must be willing to spend some money for experimentation in order to save in actual service, and to secure greater efficiency.

The navy has now in service one destroyer, one destroyer tender, and one submarine tender equipped with Parsons turbine reduction gear, and one collier equipped with Westinghouse reduction gear. There are building four destroyers with machinery of this type, three with Parsons turbines and one with Curtis. Geared cruising turbines are being used on 15 destroyers and five battle-ships built and building. The electric drive has been tested out on one auxiliary vessel, and is being installed on three first-class battle-ships building. In the matter of electric drive for propulsion of ships our navy is the pioneer. This is entirely an American development, and the men responsible for its initiative and its development to a successful point are all Americans. The Navy Department has materially assisted in this development. An experimental Diesel engine, the largest yet to be installed on a vessel, has been completed at the Navy Yard, New York, and is now being installed on the oil-fuel carrier "Maumee," which has been towed there from San Francisco. This 2-cycle Diesel engine, of 5,200 h.p., was built by the Government. The tender "Fulton" has been equipped with a 2-cycle Diesel engine and has been in service for over a year.

Among the new things in the auxiliary machinery of naval vessels, it may be mentioned that the small steam turbine has been developed as the accepted drive for forced-draught blowers on nearly all our naval vessels. In this also the United States has been the pioneer. The use of gearing for turbine-driven generators, pumps, and blowers has also been initiated. Rotary pumps are now being used for oil-fuel service.

Condensers.—The principal improvement in condenser practice has been the adoption of expanded tubes in place of packed tubes. Expanded tubes can be kept absolutely tight, while there is always some doubt about a packed tube. For some years expanded tubes have been used on destroyers. For large vessels the tubes have been expanded at inlet end and packed at outlet end. This prevents crawling of tubes.

Augmenters, dual air pumps, or some kind of dry vacuum apparatus are installed. Tube spacing to allow of least possible resistance to flow of steam is being employed.

Steam ejectors in combination with a condensate pump have been experimented with, and their use is being considered. These ejectors save a great deal of weight and space, but they will have to be thoroughly tried out before they can be generally applied.

The importance of high vacuum is fully appreciated, and no effort is spared to obtain all possible advantage within the limitations of the design. On turbine vessels the design contemplates securing a vacuum of about 28in. to 28½in. of mercury at full power, with circulating water at 70° Fah. At lower powers a better vacuum is obtained. On destroyers and scouts scoop injection condensers are being used, with a small auxiliary circulating pump to furnish circulating water for backing and while vessel is standing still or manœuvring.

Feed Pumps.—Turbine-driven multiple-stage centrifugal feed pumps are being installed on our latest vessels. It is expected that these pumps will be more reliable, furnish a more steady pressure, and be considerably more economical, especially in repairs, than the reciprocating plunger pumps that they supersede. It is also expected that the centrifugal pumps will require far less overhaul and will lessen the danger of rupturing feed piping.

Rotary Pumps are being adopted for fuel oil service. These pumps give a more steady pressure.

CO_2 *Refrigerating Machines* are being used in place of dense-air ice machines. Some of the later machines are electrically driven, but there is no very special advantage in the electric drive. Small electrically-driven refrigerating machines of several types have been developed for use on destroyers and small craft, these being similar to machines used in yachts and private houses.

Distilling Plants of multiple-effect, low-pressure (operating under a vacuum), non-scaling type are being fitted, and auxiliary exhaust is being extensively used for operating evaporators. These steps have resulted in materially reducing the fuel consumption in port. The use of feed heating in connection with distilling plants is being extended and consequent gain in economy realised.

Clutches for connecting or disconnecting cruising units or motors while shafts are revolving have been experimented with and installed in a number of vessels; some are hydraulic oil clutches, others magnetic. A thoroughly reliable clutch for this service is very desirable, and from the different kinds tried it is hoped that several will be developed beyond the experimental state in the near future. The clutches used are the Metten clutch, operated by oil pressure, the Turner mechanical clutch, and the magnetic clutch manufactured by the Cutler-Hammer Company.

Forced-draught Blowers.—Tests and experiments have been carried on for several years in order to develop forced-draught fans for destroyers that will be both strong and durable, and which

will operate as noiselessly as possible. This is an extremely important matter, as the noise of these fans is one of the things that will disclose the presence of a destroyer to an enemy; it also indicates lack of efficiency.

The Gyroscope, besides its entirely successful application in the gyroscopic compass, which is now installed on all naval vessels of fighting value, and which has made submarine navigation practical and reliable, is also being used in numerous other fields, such as a stabliser for air craft, submarines, and for other naval craft.

Radio Apparatus.—In the field of radio development tremendous strides are being made. The range of apparatus on naval vessels has been doubled. Trans-Pacific stations are being built to connect the radio chain across the Pacific from San Diego to Cavite *via* Pearl Harbour. The wireless telephone is also being developed in conjunction with the radio stations.

Standardisation of Engineering Apparatus.—Another vital matter involving naval engineering preparedness is the standardisation of engineering methods, tools, gauges, fittings, parts, &c. Comparatively little has been done in this matter, and the difficulty seems to be to get someone or somebody to start things. The American Society of Mechanical Engineers and other engineering societies have laboured in this field, but definite progress is not satisfactory.

Standardisation of mechanical apparatus is essential to the maximum efficiency of the naval engineer. Whenever standardised commercial articles can be used the Department is desirous of so doing, as a standard commercial article is (1) more quickly obtained, (2) allows increased competition, (3) will be cheaper, (4) will necessitate carrying a smaller stock of material, (5) and can be obtained readily when away from the source of supply.

Steps towards standardisation have been made along the following lines: (1) Boiler-tube specifications of the American Society for Testing Materials, the American Society of Mechanical Engineers, and Railway Master Mechanics' Association are recognised by law in several of the States; (2) spark plugs for gas engines are fast coming to a standard size with a standard screw thread.

The Navy Department has always been in favour of standardising mechanical apparatus, and of late years we are trying hard to fix matters so that the best commercial practice in any field will be suitable for naval work. Standardisation in many particulars is essential, and the manufacturers and mechanical engineers of the country should be making special effort to secure further standardisation of methods, tools, and parts. In the end, the engineering industry of the country will benefit by this standardisation, and engineering material and apparatus can be more economically supplied.

Co-operation of Engineering Activities.—The naval engineer, both in and out of the service, has many new and interesting problems before him, and it behoves him to be looking to the future to employ the best that science and mechanical ability can provide for fashioning the weapons of naval preparedness. The best development of naval engineering matters will be accelerated by the best possible co-operation between the naval and the industrial engineering talent of the country. Without this hearty co-operation and the support of the engineering facilities of the country, the navy could not be properly placed or kept upon a war footing. In fact, without the utilisation of the civilian engineering talent of the country we would not get very far with our material for the navy. The navy appreciates the need of this co-operation, and desires that our commercial engineering forces co-operate in every possible way to give it the best material that American engineering talent can devise and that its mechanical forces can fabricate.

But not only should there be co-ordination between the civilian engineer and the engineer in the navy, but there must also be that co-operation and standardisation of engineering means and efforts that this Society aims to foster and in which it has been so markedly successful.

L. & S.-W. Railway Electrification.—The electrification of the Claygate portion of the London & South-western Railway Company's suburban lines has now been completed and a half-hourly service of electric trains between Claygate and Waterloo, covering the journey in 29 mins., commenced on Monday last.

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1916.

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Steam Engine Tests and Working Results.

In his annual memorandum to the Manchester Steam Users' Association, Mr. C. E. Stromeyer, the chief engineer, gives a classified table of the coal consumption of steam engines of various types used in the textile and other industries. The figures are instructive as showing the range of economy measured in this way of similar types of engines employed in the same industry, and the difference that exists between these values and those usually guaranteed by makers for test results when engines are laid down. Although the economy of engines is usually expressed in pounds of coal per indicated horse-power per hour in commercial circles, this method of measurement, as engineers know, is very imperfect, as it includes the combined performance of both engine and boiler, and the efficiency of one may be quite independent of the other, the function of the boiler being to generate steam and that of the engine to use the steam with the greatest efficiency. The boiler may be extravagant and the engine economical, or vice versâ, but the coal consumption per indicated horse-power per hour only expresses the combined results, it does not differentiate between them. Further, such a figure takes no account of the quality of the coal itself, and it may be that the use of a low-grade fuel would give a higher consumption per unit of power and still be economical from a monetary point of view. It is difficult to compare the power results of engines in textile mills with those in other industries on the coal basis alone unless the amount of fuel used for other than power purposes is clearly ascertained. In the textile industry this is a fairly large quantity, but as the steam is drawn as a rule from the same boilers which supply the engines it is not easy to assess it exactly, but the estimate of 0·6lb. per indicated horse-power per hour given by Mr. Stromeyer for spinning mills is probably not far from the mark. Making this deduction, and taking an average of the figures given for engines

of 300 h.p. and above, it would appear that the consumption in the case of compound engines using steam of 100lbs. pressure is about 3lbs. of coal per indicated horse-power per hour, and for high-pressure compound engines using steam round 160lbs. pressure the consumption is about 2·15lbs. For triple-expansion engines using steam at 168lbs. the figure of 1·65lbs. is given. These figures textile millowners will note are perceptibly higher than the results usually promised by engine builders and generally attained during trials, but it should be remembered that tests are usually made under as favourable conditions as it is possible to secure, and do not take account of the fact that apart from the requirements for heating purposes, to which reference has been made, a factory engine as a rule stands idle for about two-thirds of its time, and that a considerable amount of fuel has to be expended each day in raising steam first thing in a morning and in banking fires the last thing at night. This amount again is somewhat uncertain, though we think the estimate of 0·3lb. per indicated horse-power per hour a fair one, and if this be taken from the figures above the rates of coal consumption for the net production of one horse-power hour under working conditions work out approximately as follows:—

Old compound engines using 100lbs. pressure, about 2·7lbs.

High-pressure compound engines, about 1·85lbs.

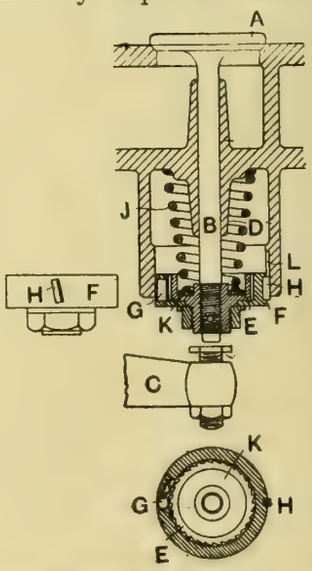
High-pressure compound with superheated steam, about 1·45lbs.

Triple-expansion engines, about 1·35lbs.

We have mentioned that it may be profitable to use a low-priced fuel even though the coal consumption appears to compare unfavourably, and on this point Mr. Stromeyer makes some pertinent observations which have a bearing on the national duty of economising coal, a duty which will probably become more impressed on us—with flux of time, and which is specially important at the present, when ships are scarce, freights high, and our Allies' needs greater than ever. In this country there has been a tendency both amongst colliery owners and steam users to discard low-grade fuel. When good qualities could be had cheaply there was something to be said for this attitude, but that day has gone by, and the use of poor fuel presents opportunities which as a nation it behoves us well to consider. According to coal experts 25 per cent., roughly speaking, of our coal measures are not utilised on account of the seams being thin or of poor quality, although such fuel might be easily used in our factories if boiler capacity were increased. On the Continent such coal is burnt to a great extent simply because better quality cannot be obtained, and, what is more to the point, the efficiency of their boilers is as a rule higher than our own, for the simple reason that with our superior coal we overwork them. Similar remarks apply to the burning of coke, which might be a valuable by-product of works devoted to the distillation of coal. At present, however, its production is limited, and consequently its price high, so that it presents little temptation to the steam user, who again regards the question from the boiler point of view and notes only that more fuel would be required for the same work. This attitude may be more profitable possibly to the individual, though that is arguable; but there is no doubt, speaking nationally, it is wasteful. We have not, in fact, in this country sufficiently considered as yet the potential economies of fuel, though the time is not distant when it will be inexorably forced upon our attention by the water-power resources of other countries, like Sweden, Norway, and Switzerland, which hydro-electric power generation and distribution will eventually bring into serious competition with British coalfields in industries where large quantities of power are concerned. Our coal beds will not always give us a monopoly. Taking coal at the pre-war price of 12s. 6d. per ton, and assuming coal consumption to be only 1lb. per indicated horse-power per hour, Mr. Stromeyer states that the total cost, including wear and tear, in one modern factory working about one-third its time, was found to be about £12 per indicated horse-power per annum and that working day and night it would be about £6. These figures compare very unfavourably with 35s. to 50s. per electric horse-power per annum which is given as approximately the cost of continuous hydro-electric power production in the continental countries we have named. The problem of utilising low-grade fuels is one that offers many solutions to which we may refer on a future occasion; it is sufficient here to state that it offers big possibilities of economy, if only the power user, the engineer, and the chemist work together.

VALVES FOR INTERNAL-COMBUSTION ENGINES.

WITH a view to reduce the uneven wear of the valves of internal-combustion engines, and particularly valves having mitre or flat seats, due to the pitting, erosion, and distortion which take place by reason of the heat to which they are subjected, Mr. Charles James, of Spittlegate Ironworks, Grantham, has designed the arrangement shown in the accompanying cuts. A is the valve carried by the spindle B, which is designed to be reciprocated axially by the lever C in the guide casing D. A ratchet wheel E is keyed upon the lower end of the valve



VALVE FOR INTERNAL-COMBUSTION ENGINES.

spindle B, and a ratchet driver F loosely encloses the ratchet wheel in such a manner that it can rotate relatively therewith, but moves axially with the valve and spindle. The ratchet driver F is furnished internally with one or more pawls G, one only of which is shown, and externally with a key or feather H, the key or feather being placed at an angle to the vertical, as shown, and engaging in a spiral keyway L in the guide casing D. With this construction, when the valve A is opened (or closed) the ratchet driver F, which moves axially with the valve spindle B, has a slight degree of rotary motion imparted to it, due to the engagement of the key or feather H with the spiral keyway L. This rotary motion is transmitted by the pawl or pawls G to the ratchet E, and as the latter is rigidly secured upon the valve spindle B, the latter, with the valve, is partially rotated, this partial rotation taking place every time the valve is lifted, and the pawl G being returned to its initial position on the valve again closing. As will be understood the amount of rotary motion that is imparted to the valve is determined by the angle of the spiral keyway L. The closure of the valve is effected in the usual way by means of a spring J, which is held by friction against the top of the guide casing D, and acts directly on the valve through the medium of a thrust-bearing washer K, which is supported upon the ratchet wheel E.

SPRINGS.*

BY C. E. SQUIRE.

To appreciate a little more fully some of the later points of the present paper, it is advisable to define as exactly as possible what a spring is. A spring can be made from many different materials—steel, bronze, and india-rubber being those generally used. It can be made in many different forms, and be used for many purposes, but there are six principal kinds:—

(1) *Cylindrical or conical helical springs subject to axial loading*, the material being mainly subject to torsional stress. This is the form that has the widest application; it is used largely on railways and tramways, for many kinds of valves and a variety of engineering purposes, for upholstery, *e.g.*, sofas and mattresses, and also the form generally used in measuring instruments, such as spring balances.

(2) *Cylindrical helical springs subject to torque about the axis*, in which the material is subject to bending. This form is not much used, but as examples there are balance springs of best chronometers, springs in tumbler switches, and the motive power of spring roller blinds and some cheap mechanical toys.

(3) *Flat spiral springs subject to torque about the axis*, the material being subject to bending, such as are used for watch and clock main and balance springs. It is the form generally used where it is required to store energy, *e.g.*, gramophone motors.

(4) *One or more straight or curved pieces subject to bending*, used in a great variety of cases, *e.g.*, railway and road vehicle springs, and generally where it is required to absorb shock; many kinds of instruments, such as the small springs in firearms, pocket knives, latches and locks, and many other uses; in fact, class (4) with class (1) include the great bulk of springs used.

(5) *India-rubber springs, generally subject to compression, but sometimes to tension.*

(6) *Gases in closed vessels*, such as pneumatic tyres and the air chambers on pumps.

This list does not cover anything like the whole of the forms or uses of springs.

Springiness comes into all sorts of problems, and it is not easy to word a definition to cover all the cases of what is generally understood as "a spring." The author has not found a better definition than that of Prof. Perry: "Any contrivance that can store energy as strain energy, and give it out again readily is a spring." On this point one must remember that whatever its material, form, or purpose, a spring is always a contrivance for storing energy.

Historical.—To turn for a moment to the historical side. Who made the first spring? When one considers how ubiquitous the spring is, one is tempted to say Adam. At any rate, the first springs were made in the very early days of the human race, probably either in the form of some kind of trap or else in the form of a bow. The earliest references the author can find (*a*) Genesis xxi. 20, "he . . . dwelt in the wilderness, and became an archer"—that would be about 2,000 B.C.; and (*b*) 2 Chronicles xxvi. 15, "he made in Jerusalem engines, invented by cunning men, to be on the towers and bulwarks to shoot arrows and great stones"—date about 810 B.C. There are records of war engines on the Assyrian remains, but the first authentic record in classical literature of a large siege train is 399 B.C., when Dionysius I. of Syracuse provided himself with engines for his expedition against Carthage. The spring part of these old catapults generally consisted of twisted hide or sinews. Some of them would send a ½lb. missle at an effective man-killing velocity rather over 400 yards, but the largest, the "90-pounders," had a much smaller range.

Steel was introduced for the springs of crossbows about the tenth century, and the wheel lock was invented in Nuremberg in 1517. This was a sort of musket, in which the charge was fired by the sparks produced by a piece of flint pressed by a spring against a steel wheel. When the trigger was pulled the wheel was rotated by means of another spring which had previously been wound up. Nuremberg was also the place where the next step was made in the invention of watches at the end of the fifteenth century. It was in connection with watches that the first scientific work on springs of which there is any record was done. Robert Hooke, who first formulated the law we know as Hooke's Law, in his work "De Potentia Restitutiva" (London, 1678), says that he first found out the theory of springs 18 years before, but did not publish it because he wanted to obtain a patent. He says, "About three years since His Majesty was pleased to see the Experiment tried at Whitehall, as also my spring watch. About two years since I printed this theory at the end of my book on Helioscopes, 'Ut tensio sic vis'—that is, the power of any spring is in the same proportion with the tension thereof." And, later on: "From all of which it is evident that the Rule of Nature in every springing body is that the force or power thereof to restore itself to its natural position is always proportionate to the distance or space it is removed therefrom."

Very little is mentioned by historians about steel springs, but they were first applied to carriages about 1670, prior to which the most luxurious coaches were suspended by straps, though doubtless these in connection with a not too rigid framework acted to some extent as springs. The first record of the use of springs on railways is George Stephenson's patent of September, 1816. One of the problems that had so far faced the pioneers of steam locomotion was how to adjust the weight of the engine to the strength of the rails, and Stephenson solved this by means of steam-bearing cylinders fixed to

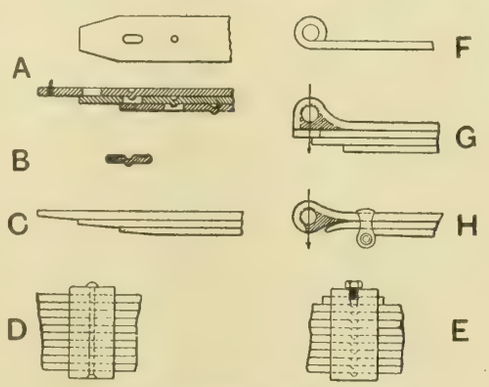


FIG. 1.—LAMINATED SPRING DETAILS.

the lower part of the boiler. Any oscillation produced by the inequalities of the road were transferred from the axles by means of rods to pistons working in these cylinders which, acting against the steam pressure, performed the office of springs. There was better distribution of weight and less injury was done to the rails and machinery, and it was possible in consequence to still further increase the weight and power of the locomotive. This spring arrangement was considered a noteworthy feature of the Killingworth engines as late as March, 1822. The engines which opened the Hetton wagon way on November 18th, 1822, had them, although steel springs had been employed a year or so previously.

The first locomotive with steel springs was the "Agenoria," built by Foster & Rastrick in 1820 and now in South Kensington Museum. This had laminated springs on the leading wheels. By 1830 the use of springs had become fairly general. The railways have since been good customers of the spring maker, and although the trade is divided into several sections whose products and methods differ very considerably, the heavy section, dealing mainly with railway work, is the most important. Indeed I think that the value of the springs supplied to the railway companies very much exceeds the value of the springs for all other purposes put together, and must in normal times reach the figure of £10,000 per week, manufactured in this country alone and mostly in Sheffield and district.

In view of their greater importance both from a financial point of view and because safety of life and property depends on them, the author proposes to confine his remarks mainly to springs for railway use, although, of course, they will apply equally to similar springs used for other purposes.

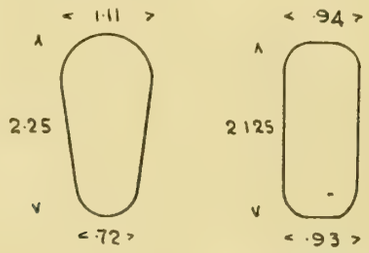
Manufacture of Laminated Springs. In the manufacture of laminated springs the rolled bars are first cut to length,

* Paper read before the Junior Institution of Engineers, November 20th, 1916.

then generally, but not always, the spring plate is "speared" (*i.e.*, the corners are cut off) and nibbed and slitted (*i.e.*, a little stub or nib is pressed into the plate fairly near the end which fits into the slit in the next plate so as to prevent relative movement sideways of the ends of the plates and a hole or stud put in the centre), Fig. 1 (*a*). An alternative to the nibs and slits is to roll the spring bars with a longitudinal rib and groove down the centre, as shown at (*b*), the rib on one plate fitting into the groove on the next. In this country, at any rate, it costs more than the nibs and slits and it is very little used anywhere except on the Continent.

Sometimes, particularly in the better-class work, such as railway carriage springs and almost always for road vehicle springs, the ends are tapered in a pair of eccentric rolls (Fig. 1 (*c*)), this thinning being either in addition to or instead of the spearing, and its object is to keep the resisting moment of the spring as nearly uniform as may be at all sections, and thus obtain a lighter spring without reducing the strength.

As the greatest bending moment is at the centre, the method of fastening the spring together is rather important. The usual way is to put a rivet right through the centre and through the buckle (Fig. 1 (*d*)). This is quite satisfactory, as the buckle is generally not less than 3in. wide, and is pressed on hot, and so makes up for the loss of strength by the rivet holes in the centre of the spring plate. It is often urged that these holes should be drilled or else punched hot, on account of the internal stresses set up by cold punching, but the author is of opinion that the subsequent heat treatment removes these stresses, and tests made by him support this view. It is essential, however, that the holes, whether drilled or punched, should be kept as small as possible, say,



As rolled. After coiling. Diam. of Mandrel 2⅜in.

FIG. 2.—CHANGE OF SECTION IN COILING.

$\frac{1}{16}$in. less in diameter than the thickness of the plate, and it requires very good machines and punches to punch, "cold," a $\frac{9}{16}$in. hole through a ⅜in. spring plate.

To reduce the effective section of the plate at the centre as little as possible, the rivet hole is sometimes made ¾in. by ¼in. lengthways of the plate, and another method is to nib the plate, the nib fitting into a corresponding depression in the next plate and to fasten the buckle centrally by a set screw (Fig. 1 (*e*)), but it is questionable whether either are worth the cost.

The ends often have eyes to carry a pin which may be made either by bending the plate round (Fig. 1 (*f*)), or by welding in a piece of iron to form a solid eye; the pin hole being afterwards drilled out, and perhaps a slot milled in the end. These heads are made in various forms, the two shown being the most common. Of these Fig. 1 (*g*) is the best. The weak points in the top plates are: (1) The central rivet hole already considered. (2) The nib and slit, which are generally avoided in the top two or three plates of this type of spring by using a shackle as shown in "h," bolted to a rolled eye on the end of the third or fourth plate. (3) The weld. (4) The part of the plate in the neck where the weld terminates. To get a sound weld, the steel must be heated very nearly to the point at which it will burn, and the strength of the neck is liable to be reduced from this cause. Now in Fig. 1 (*g*) the back plate can be supported right up to the end by the second plate, or more, if necessary, and, if the back did give out in service, it is probable that the broken end would remain supported by the other plates. In Fig. 1 (*h*) not only is the load carried by the weld but, owing to the relative movements of the plates when the spring bends under load, it is not possible to support the back plate further up than, say, 3in. or 4in. inside the centre of the eye, and there have been cases where the back plate has taken a reflex curvature near the end of the second plate, due to excessive stress there, and in time has given way. It speaks well for the skill of the smith that a broken plate is of very rare occurrence. The end of the back plate is sometimes bevelled off instead of being square, as shown, but this bevel should not be too acute, otherwise there is trouble in withdrawing the head from the die in forging, and in any case the second plate does not support it as well as when the corner is square. Sometimes the plates are of varying thickness, but generally this is not economical, as it reduces the range of the spring to that suitable for the thickest plate, and one is not so certain of getting a uniform working stress in all the plates. It is better to have one thickness only, except in special cases, and even then it is very rarely that a difference of more than $\frac{1}{16}$in. should be used.

The plates are next heated and bent to the required curvature and hardened. The old way is to bend the longest plate by handwork to fit a cambered plate, which is used as a sort of templet or jig. This back is then hardened and tempered, and the second plate bent to fit the back plate, and so on. No matter how much care is exercised in bending and hardening, there is always a certain amount of warping in the hardening which has to be corrected by hand fitting afterwards. The tempering is done in a furnace, the operator withdrawing the plate from time to time to judge the temperature. He does this by rubbing a piece of hard wood on it, which smokes when the plate is about 550° Fah. At about 650° it leaves a number of bright particles on the plate which burn without flame, "sparkle," as it is called, and at about 800° the wood bursts into flame. It seems rather a crude way, but it is surprising what skill and accuracy the men attain by constant practice.

In bending the plates, the fitter always bends the hot plate to a slightly less radius of curvature than the previous plate, and so, when the finished plates are put together, but not bolted up, they touch each other at the ends only, leaving a space at the centre. This is called regulating the spring, and the space is greatest for the longest plate, diminishing regularly towards the shortest. A second method is to bend the plates in bending rolls one at a time, and a third to bend all the plates for one spring together at one time between dies under a hydraulic press and to harden them at the same heat which can, of course, be done in the rolling process also. In both these cases the tempering and hand fitting follow as in the first method.

There is some controversy as to which is the best method. It would certainly seem, on the surface, as if it was not possible to produce the regulation by the last method, but let us consider what is the purpose of the regulation. When the spring is fastened together at the centre so as to draw the plates together, there is a tendency for the ends of each plate not to bear on the next plate, particularly if the fitting is not good, and no spring will pass inspection if the plates are at all open at the ends. The fitter makes sure that they do not open by putting in plenty of regulation. Perry says: "I think carriage spring makers and buyers are too particular in their wishing to have all the plates lying very tightly together when bolted up. There is too much of such tightness. Usually, too, in actual use a carriage spring never becomes unloaded, and its plates are, therefore, much more tightly pressed together than when the spring is examined unloaded." He further indicates how the amount of regulation may be calculated so as to obtain a uniform stress in all the plates, but much the best work in this direction is that of Monsieur Phillips, who published a paper on the Mathematics of Laminated Springs in 1852. The author believes that Phillips was a practical railway engineer, and it is a pity his work is not more widely known.

Taking an actual example, the author has found that the correct space between the two longest plates in a spring 3ft. 6in. long, having 12 plates 3½in. by ½in. and 4in. free camber, is only about $\frac{1}{16}$in., and my experience is that, with the most skilful hardening, the plates will often warp considerably more than this, and so one arrives at the conclusion that there is no real difference between the methods of bending the plates, except convenience, by "hand" being best suited for oddments and the "machine" for repetition work. The press gives the most uniform results, but in some cases costs more, owing to dies, &c.

Every spring is tested under a steam scragg to about twice its working deflection, where possible, and about 3 per cent. tried for deflection under load, in a compression testing machine. The springs are taken apart and the plates painted, and then an iron buckle put on hot and closed up with a press. Some inspectors scragg the springs with the buckle on,

but the author thinks this incorrect, owing to the difficulty of detecting a broken plate; but this matter is not so serious now that the scragging strokes have been standardised by the Engineering Standards Committee.

Manufacture of Coil Springs.- Coil springs are of two main types, helical and volute. Helical springs are made of either circular or rectangular section, and it should be remembered that a section of bar that is to be rectangular after coiling will not be rectangular before. Fig. 2 will illustrate the change that takes place. The shape of the rolled bar not only varies with the shape of the finished section, but also with the diameter of the mandrel on which it is coiled. You will readily see the very large number of shapes that have to be rolled, and the cost is generally more than for the round bar. One can afford to stock round bars, but that is out of the question for rectangular bars, except in a few regular lines, on account of their very great variety. In any case it is easier to get rounds through than to get the mills to put in special rolls for an odd lot of bevels, and this may easily save two or three weeks' time in delivery. This is one good practical reason in the favour of the round section, and it can show many others. In fact, in America it is almost the only section used. After coiling, the ends of the spring are trimmed up by a smith, and it is then "set up," *i.e.*, pulled out to the proper height for hardening. It can sometimes be coiled at the proper pitch, but generally the pitch is so steep that there is a great tendency for the section to lay over on its side. The spring is then hardened in whale oil and tempered in a bath of molten lead and then scragged. The ends are ground up square with axis, and it passes much the same inspection as a laminated spring.

Testing.—Sometimes a spring is given 100 severe blows, taking it through its whole, or nearly its whole, range. The test is directly opposed to the principles set up by the researches of Wohler, Baker, and others, and the only information it gives is that the spring has stood 100 blows, but it does not make one any more certain that it will not break at the 101st; in fact, rather the reverse. The author is convinced that to press a spring home smartly two or three times is quite effective in bringing to light any latent defects, and that further testing shortens the life of the spring and is detrimental, especially where the spring is of indifferent design. To make a good spring three things are necessary—good design, good material, and good workmanship. As far as the last two are concerned, Sheffield can more than hold its own with all competitors, but it is a question whether we are not rather behind on design. It would be impossible to fix the responsibility for this, but if engineers spent one-tenth of the money they pay for checking the material and workmanship in checking the design, the results would more than justify it.

(To be continued.)

REFRACTORY MATERIALS.

DISCUSSION BY THE FARADAY SOCIETY.

(*Concluded from page 406.*)

THE MANUFACTURE OF REFRACTORY MATERIALS.

BY ALBERT CLIFF.

IN this contribution the author treated the subject from the makers' point of view. Various suggestions were made as to the directions in which improvements in manufacture were possible. One was in the reworking up of old material; this would be one of the best means of eliminating expansion and contraction. In the basic and neutral groups of refractories there was an inviting prospect for the application of manufacturing skill. Some of the present temporary difficulties in the supply of materials he himself was overcoming by fastening working surfaces of chromite, magnesite, or other material not liable to corrosion on to ordinary fire or silica bricks. Some samples of these faced bricks were exhibited. As a manufacturer he advocated the closest possible union between the chemist and the craft in the carrying out of organised investigations—mere laboratory tests were insufficient—into the commercial value of the minerals, chromite, magnesite, graphite, and others, reported that evening as abundant in the colonies. Above all, improved education was necessary in those who were to carry on the business of making refractories; the men of science must come down to them and talk to them freely of principles and facts, and so accelerate a rise of specialised intelligence among clayworkers.

CLASSIFICATION OF REFRACTORY MATERIALS.

BY E. P. PAGE.

This paper is confined in the main to the materials used in the heavy industries. To cover the whole field of refractory materials and their application in large branches of industry would be beyond the range of accomplishment in any single paper. The collection and tabulation of facts is a laborious task, since much of the information is only to be obtained by the association of those who are engaged in industrial practice. Further, the science of refractory materials is in its infancy, and much of that which is considered to be the fact requires verification. An easy method of classifying refractory materials has been to divide them into three sections, namely, acid, basic, and neutral, according to their chemical composition and their behaviour towards each other and the acid or basic compounds brought into contact with them under such conditions as are favourable for reaction to take place. The classification is somewhat arbitrary, because a clay such as china clay must be expected from its chemical composition to be a neutral material, which experience shows is not the case, and it is customary to include all refractory clays in the acid class. The essential property of any material claimed to be refractory is stability at the temperature to which it is exposed, with sufficient reserve of stability to resist chemical and mechanical influences externally applied. The first quality is a classification of pure refractoriness, and the second is one of refractoriness plus skill in application. However, since purely basic or purely acid conditions seldom exist, the successful issue is generally the result of compromise, a certain degree of refractoriness *per se* being sacrificed in favour of an increase of refractoriness against other things. Materials belonging to the acid class are always used where it is a case of refractoriness towards heat, because they are widely distributed and comparatively low in first cost and lend themselves rightly to adaptation to all purposes. Suitable basic and neutral materials, on the other hand, are not so widely distributed, and possess in important instances inherent properties which render them difficult of application.

Mr. A. A. McDougall Duckham, of the Ministry of Munitions, emphasized how much the output of munitions depended on refractories. It was clear that we had at home and in the Empire ample material to enable us to hold our own.

Dr. W. Rosenhain, F.R.S., of the National Physical Laboratory, spoke of the necessity for paying attention to the highest class of refractories, now that metallurgists, especially in the electric furnace, were utilising very high temperatures. Metallurgists should know all about materials like carborundum, alundum, silicon, and similar products now being produced at Niagara Falls. There was great promise in zirconia, especially the highly purified material. An analysis of crude zirconia (about 75 per cent. pure) was given. This material fell far short of pure ZrO_2 in refractoriness, but still bricks made of it would resist temperatures up to 1,600° C. To get the best results it was essential to shrink the material at a much higher temperature than that it would have to stand eventually, particularly because it was so bad a conductor of heat. The crude zirconia was greatly improved by removing the chief flux, namely, the iron oxide, with hydrochloric acid. Zirconia bricks as now purified for optical purposes do not frit until well over 2,000° C. Dr. Rosenhain went on to discuss the cracking of refractories. This was caused by physical forces involving nothing but determinable constants, and the coefficients of thermal endurance could be worked out, as had been done for glass.

Prof. T. Turner (Birmingham) reminded the meeting that the subject was also of interest to the glass, pottery, and porcelain industries, and he referred to the work on glass being done at Sheffield University. Speaking of the relation between porosity and the packing of the grains of which the material is built up, he pointed out that round grains did not necessarily mean an open and sharp a close packing. Small round particles in the interstices of larger round ones, as one might have in sand, gave the closest grain. Porosity had been measured by drawing air through at a known rate.

Dr. R. S. Hutton (Sheffield) pleaded for more work at the very high temperatures of the electric furnace. For example, the properties of completely shrunk magnesia were quite different from those of ordinary calcined, and the shrinking could be economically effected electrically.

Dr. W. H. Hatfield (Sheffield) remarked on the work to be done on the resistance of refractories to slag erosion. He gave examples of the great disparity in behaviour of different grades of silica bricks. Before more progress was possible much more accurate instruments for registering high temperatures were necessary; at present, calibration between 1,000° and 2,000° C. was difficult and uncertain.

REFRACTORY SANDS.

BY DR. P. G. H. BOSWELL.

Many of the sands used for refractory purposes are not true sands in the geological sense; they frequently contain a proportion of refractory clay, &c. There is no doubt that we can replace from home resources a large proportion of the refractory sands hitherto imported from abroad, but the extent to which this can be done will not be completely known until further investigation of the properties of suitable materials and satisfactory substitutes has been carried out. The admirable work of H.M. Geological Survey in collecting, recording, and, in part, subjecting to analysis supplies of refractory materials worked in this country needs to be supplemented by much research work, for in certain directions the properties of desirable sands, for example, are not fully known, and geologists do not know what to look for. Pure academic work in the shape of the application of modern petrographic methods to the investigation of sands is urgently required, but the final tests of the suitability for particular purposes must always be on a commercial scale in the works. On the academic side, we need far more results of experiments and observations carried out on certain definite lines and under standard conditions, with continuity secured by the retention of one worker or set of workers in each direction. The time has passed for the scattered and haphazard methods and results of which we have had so large a number. The pure scientific work will indicate the likely materials to be tried in industrial practice and will eliminate the improbable. The closest British analogues to the very suitable foreign materials will then be found.

The refractory sands used in industry may be divided into three chief classes: (*a*) the high silica sands (with 98·99 or more per cent. of SiO_2), (*b*) the high silica and alumina sands bearing variable proportions up to 20 per cent. alumina, as kaolin, &c., and little else but silica, (*c*) sands for green sand moulding, carrying a strong and highly refractory natural clay bond. All class (*a*) sands hitherto imported may be replaced from the abundant and excellent British supplies. (The economic factors, freight, &c., will have to be considered.) We have also valuable deposits of class (*b*), but so far as those sands of class (*c*) which are used for high temperature steel-moulding are concerned, it must be admitted that the best of foreign sands hitherto used here have not been equalled by known British resources. The reason for this is twofold: in the first place the peculiar properties of the Belgian red or yellow sands, to take a concrete case, have never been thoroughly investigated with the view of finding substitutes; in the second, we do not yet know all our British sand and related deposits at all thoroughly. At least two geological horizons in this country should be thoroughly searched in this connection; they are the Pliocene and the Lower Cretaceous. The Tertiary and Cretaceous deposits of the south-west of England are particularly deserving of attention.

In brief, research on British and foreign refractory sands is desirable in the following directions (among others): (1) Mechanical analyses, to gain more accurate ideas of grading, carried out scientifically; (2) chemical analyses of each grade, not bulk analyses; (3) mineral analyses, to realise the importance of constituent minerals, especially those prone to decomposition which yield the "bonds" of these sands; (4) the water-holding capacity of 10° intervals at temperatures below 110° and at suitable but greater intervals above; (5) the conductivity; (6) the refractoriness of each grade; (7) pore space and permeability.

It is to be hoped that before long a detailed account of British resources of refractory sands, with analyses and notes on their peculiar properties, may be in the hands of manufacturers and others. Such a report by the speaker on British resources of sands suitable for glass-making, with notes on certain highly siliceous materials suitable for refractory purposes, was just being published at the request of the Ministry of Munitions. These glass sands fall under classes (*a*) and (*b*) above, but the resources suitable for refractory purposes are far larger than those for glass-making.

Finally, co-ordination of the work of the four classes of interested people (users of refractories, the makers of refractories, the collectors and analysts of raw materials, and the research workers) is urgently required to prevent serious overlapping and to ensure a minimum loss of effort and a maximum of benefit to the country, which as far as possible should be self-supporting in the matter of raw materials for key industries.

The general discussion was resumed by Mr. E. Kilburn Scott, who confirmed from his own experience with flame-arc furnaces what Dr. Hutton had said about the possibility of completely shrinking magnesite.

Dr. W. C. Hancock spoke of the application of certain organic dyes to etch refractory materials much as metals were etched. This method, coupled with Prof. Fernsides', would be a powerful weapon for elucidating internal structure. He was working on coke-oven firebricks in this direction in conjunction with Prof. Bone at the Imperial College of Science and Technology.

THERMAL CONDUCTIVITY OF MATERIALS EMPLOYED IN FURNACE CONSTRUCTION.

BY EZER GRIFFITHS, M.SC.

This paper dealt with the methods employed for investigating the thermal conductivity of bricks and tiles of commercial sizes. One of the practical difficulties was the attainment of a uniform temperature over the hot face of the sample, since the surfaces were always irregular. It was found possible to obtain good thermal contact as well as a very uniform distribution of temperature over the surface by the use of a shallow bath of molten metal electrically heated. In high temperature experiments the heating was effected by making the test sample a part of the walls of a large muffle. The heat transmitted was measured by a flow calorimeter fitted with a guard ring.

A compact form of thermo-element was described: the two wires (Pt—Pt 10 per cent. Ir) being separately insulated by silica capillaries and both enclosed in a silica sheath of about 5 mm. diam. The sheath was closed at the end in the form of a bulb containing the junction. The thermo-element was employed for exploring the distribution of temperature in the metal bath, and for this purpose it was bent into an L shape.

Values of the thermal conductivity and its variation with temperature were given for two typical materials employed for thermal insulation—the one composed principally of diatomaceous earth baked at a high temperature to form a rigid brick of friable texture; the other manufactured by blowing steam through molten blastfurnace slag, which converts it into a product bearing a resemblance to cotton wool. This material was tested in the form of a mat, the faces being covered with wire meshing.

Dr. J. A. Harker, F.R.S., commented on the value and accuracy of Mr. Griffiths' work on a subject presenting serious experimental difficulties. He added some information on the properties of zirconia, which, if fine enough, would stand being plunged into water at a white-heat temperature.

The following written communications to the discussion were received:—

Mr. W. Donald (Glasgow), who sent in some specimens of raw and calcined Greek magnesite and magnesite cement and bricks, wrote that they were having to make substitutes for Austrian magnesite bricks, and they were therefore adding some 8 per cent. Fe_2O_3 to the Greek magnesite, which was too pure, to approximate its composition to the Austrian. Mr. Donald also exhibited some Indian and Rhodesian chrome ore and cements and bricks made therefrom. He went on to suggest that the use of dolomite in conjunction with magnesite for basic steel furnaces needed serious consideration. He believed that when, as often, the dolomite boils with the metal active ferrates of lime may be formed, and the result is destructive to the magnesite foundation of the furnace. He had recently suggested to the Iron and Steel Institute the desirability of drawing up standard specifications for bricks used in the iron and steel industries. Finally, he touched on the question of linings for electric furnaces, and he incidentally mentioned the possibilities of Serbia, with its minerals and plentiful water power, as an electro-metallurgical centre.

Mr A. B. Searle (Sheffield) expressed his agreement with the view that chemical analysis was secondary in importance

to some of the physical characteristics of firebricks, and he had himself chiefly relied on physical and microscopical methods of examination. Referring to the desire for co-ordination that had been expressed, he reminded the meeting that they had a trade journal which devoted special attention to the scientific and technological aspects of refractories. Backwardness was largely due to the fact that most of the firms concerned were too small to undertake research work. Furthermore, research, to be useful, must be carried out by specialists who had practical knowledge of the industry. The manufacturers should combine together and retain such men, leaving the Universities to concentrate on questions of academic interest, for which they were specially fitted.

Mr. T. Allen (Dudley) said the great difficulty in making improvements in manufacturing processes in this industry was to prove the value of any change, because this might take years to realise. Laboratory tests were often inconclusive. Nevertheless, the gas-retorts of to-day were meeting the severe demands put upon them. An important point was the economy of not running retorts after their efficiency has dropped, say in 1,000 to 1,200 days. He did not think German or American gas installations showed better results than the best of our own. He paid a tribute to the work of the Refractory Materials Committee.

Mr. F. Deansfield (Oldham) wrote of the desirability of inducing manufacturers to adopt more uniform methods. He also drew attention to the enormous loss of refractory clays lying under coal seams, due to the winning of the coal only, so that it afterwards becomes too dangerous and costly to win the clay. These materials should be carefully reserved, if necessary, by legislation. He hoped the Society would consider this problem.

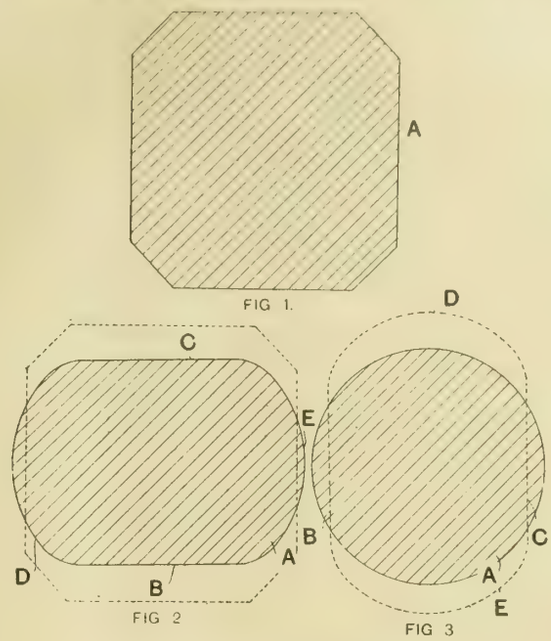
Mr. Alleyne Reynolds wrote that he knew of an Austrian works having clamped arches of silica bricks 8ft. in width that had been in use for over 20 years, whereas we were satisfied to produce silica bricks with 20 per cent. expansion. The same firm paid more attention to properly heating their ladles and shaping their nozzles than any British firm of his acquaintance. There should be more co-operation between the steelmakers and the makers of refractories. The keeping of so-called "trade secrets" was to be deprecated; the most successful manufacturers were those who showed, like their President, a large-minded scientific spirit. Mr. Reynolds disagreed with the President as to worn clay nozzles accounting for slag inclusion in steel ingots, which he thought resulted from reactions in the dissolved FeO and FeS. He was suspicious of magnesite nozzles, from which minute particles would probably be carried into the mould. He added some interesting information on the proper method of casting steel from the ladle and on the effect of iron oxides in firebricks. Fe_2O_3 and Fe_3O_4 seem to increase the refractoriness of bricks exposed to oxidising atmospheres; any iron oxide is detrimental in reducing atmospheres. The bricks forming the regenerators of open-hearth furnaces take up much more iron in the gas than in the air chambers, and their regenerative efficiency is increased. The subject needs proper investigation, as does also the volatilisation of refractories, particularly magnesite, at low temperatures, such as 1,300° C., perhaps due to catalytic action. A properly designed electric furnace was, he thought, the only remedy.

Mr. Charles R. Darling, in view of the relatively high conductivity of firebricks as shown by Mr. Griffiths, drew attention to the suggestion of Hutton and Beard, made before the Society in 1905, that furnaces should be lagged with a highly insulating substance. Experiments by Fitzgerald and by him had confirmed the great saving anticipated. It was strange that metallurgists had not adopted the idea. A very useful refractory was alundum, of which Messrs. Baird and Tatlock exhibited specimens. It melted at 2,050° C., and had no action on platinum at high temperatures, so was suitable for platinum-wound electric furnaces. A non-porous variety was useful for sheathing pyrometers and is less corroded by molten metals than silica. The question of the electrical conductivity of refractories had been little studied; in a research he was engaged upon he needed one that was non-conducting at 1,600° C. and which was not easily attacked by metallic oxides.

A considerable number of specimens of minerals and refractory materials and products were exhibited to the meeting by the authors of the papers and others.

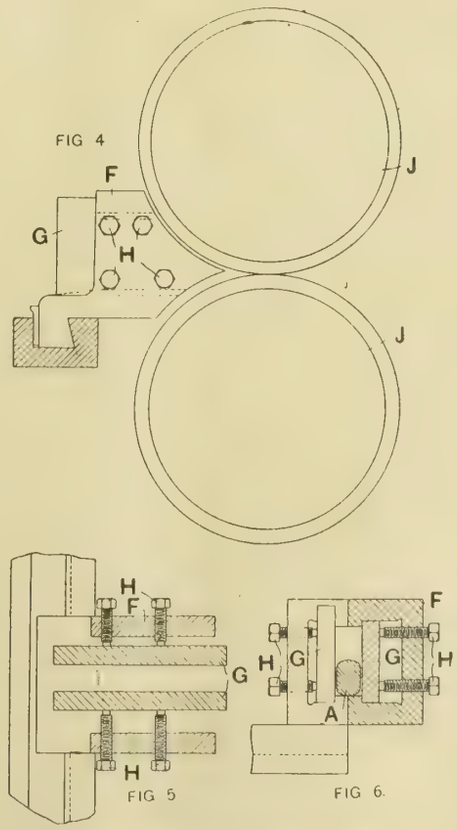
IMPROVEMENTS IN ROLLING MILLS.

In the mills at present employed for rolling round bars of steel or other metal it has been customary hitherto to form the bar when passing through the earlier rolls somewhat of oval section and to introduce this oval form into the final pass



IMPROVEMENTS IN ROLLING MILLS.

of the rolls by turning it up on its more or less pointed end and feeding it by hand therethrough, or directing it through guides upon which hydraulic or other pressure has been necessary to keep the oval bar from moving or twisting when thus being drawn through the rolls. In the arrangement illustrated,



IMPROVEMENTS IN ROLLING MILLS.

the invention of Messrs. Samuel Fox & Co., Ltd., of Stockbridge Works, near Sheffield, Mr. Charles Thickett, and Mr. William Hawksworth, the rolls are shaped for producing the round bar in such a manner that the initial stages or earlier passes of the rolls produce not an oval section but a section

two sides of which are rectilinear and the other two sides (or ends) curved in form. This specially shaped bar is then passed through the final rolls by turning such up on to one of its curved ends with the rectilinear sides vertically disposed and running between guides against which these vertical sides can bear in such a manner as to keep them in true linear position for entering the roll without liability of twisting and without needing that they should be subjected to pressure when so passing through the guides thus employed.

Fig. 1 is a view showing what might be the original form of the bar that is to be rolled into a round. Fig. 2 illustrates the form of the bar after initially passing through the rolls, and Fig. 3 shows the final section of the bar. Figs. 4, 5, and 6 illustrate in side elevation, sectional plan, and end and cross-sectional elevation one form of guide that may be adopted. The bar A, which may have an initial shape such as is shown in Fig. 1, is passed through the rolls of a rolling mill of any suitable construction so that in the initial stages it is made to assume a shape such as is shown in Fig. 2, wherein two sides B, C of the bar are rectilinear and the other two sides D, E are curved or arcuate in form, the rolls being suitably formed to produce such section. The bar is then turned up on to one of its curved sides as shown in Fig. 6, and passing through any suitable guide by which it is firmly held in position without pressure due to the contracting of the rectilinear faces B, C with the guide, is passed through the later stages of the rolls J so that it assumes finally the round form shown in Fig. 3. The guide comprises a guide box F in which are located the guides plates G, the latter being preferably adjustable by means of set screws H to enable the dimensions of the guide to be varied as may be desired. By this method of forming the rolls and guiding the bar therethrough the inventors claim they are enabled to roll without a shaped guide and more quickly and with a much simpler adjustment of the rolls and guides than has been hitherto possible, also avoiding any turning down, twisting, or lapping of the finished bar while fewer passes can be used by this process than has hitherto been necessary in the ordinary forms of rolling mills and devices employed for producing round bars.

THE USE OF POWDERED COAL AS A FUEL.*

BY JOSEPH HARRINGTON.

POWDERED coal was under consideration as a fuel over 20 years ago, and its apparent advantages have attracted the attention of engineers ever since. The early experiments were naturally crude, and failed largely because of the lack of proper machinery for reducing the coal to the required state of fineness. It was not fully appreciated that the coal had to burn while floating in the air in the form of dust. Sufficient experimentation was carried on, however, to prove that powdered coal would burn under these general conditions, and would develop a particularly intense flame. In fact, one of the chief difficulties encountered was the melting down of the furnace due to the blast-like effect of the jet of coal and air.

After the early failures there was very little done for a number of years, but about five years ago the matter was revived, and with the development of adequate pulverising machinery, extensive and practical applications have been made. The first general field of usefulness to which it was applied was the burning or clinkering of cement. The coal was not required to be pulverised particularly fine. The velocity of the jet of coal and air entering the kiln could be high, and little or no difficulty was encountered from deposits of slag or ash. The next general application of this fuel was in the simpler metallurgical processes in the heating furnaces, where excessive temperatures were not required and where the ash deposits were either continuously removed with the material to be heated or could readily settle on the hearth and be later withdrawn.

In 1912 the American Iron and Steel Manufacturing Company had carried their experimentations to a point where they were ready to publish statements of the successful use of the fuel. At the Lebanon plant they have used it in puddling and heating furnaces and small reheating furnaces for nut, bolt, and spike bars, and in larger furnaces for continuous billet heating and open-hearth melting.

Requirements of Pulverisation.—The condition in which this fuel must be furnished to produce satisfactory results has been developed to a point where it can be considered as definitely standardised. Not only for the sake of combustion efficiency, but for the sake of more perfect pulverisation the coal should be practically dry, 1 per cent. of moisture being the maximum amount at which pulverising can properly be effected. One-half of 1 per cent. moisture is the figure which is ordinarily required. Under these conditions the coal when pulverised remains quite fluid, and will break down under the influence of crushing rolls with much less expenditure of power than when damp.

In order that the fuel may remain suspended in the carrying air and in the furnace chamber during combustion, it is necessary to reduce it to a certain degree of fineness. After a great deal of experimenting this standard has been established as follows: 85 per cent. must pass through a 200-mesh screen and 95 per cent. must pass through a 100-mesh screen. When these requirements are fulfilled there is an indeterminate amount of impalpable product, the absolute size of which it is beyond our ability to measure.

Much has been printed regarding the quality of coal most suitable for pulverisation, but no arbitrary limits can be established as to the proximate analysis most suitable. Broadly speaking, the greater the volatile combustible content the more readily will the coal ignite and burn, and the less dependent will be this process upon the size and proportions of the combustion chamber. As the volatile content decreases, however, more dependence must be placed upon the proportions and location of the surrounding brickwork, in order to maintain the temperature until ignition is complete. Anthracite coal has been burned in a pulverised form, but it must be very finely ground and must be burned in a rather confined space, so that the ignition may be prompt and aid be rendered by nearby brickwork during the early stages of combustion.

Pulverising Machinery.—Several types of machinery which are commercially marketed will satisfactorily pulverise coal. They are divided, broadly, into air-separation machines and screen machines. In the former class there is an upward current of air produced by a fan which has a carrying capacity sufficient to take with it the finest particles, but which will not lift the coarser ones. As soon, therefore, as the coal is reduced to the required degree of fineness this air current will lift the particles and take them away and will then deposit them in a receiving tank by means of a cyclone separator, which is usually vented in some manner to prevent the loss of dust. In the screen mill the coal is continually thrown against a screen which permits the fine particles to pass through but causes the coarser particles to fall back under the rolls. Pulverisation can be effected in a tube mill or ball mill with an expenditure of power and cost not greatly different from that of the other types.

The Burner.—The pulverised fuel being collected in a hopper is conveyed either by screws or pneumatic means to the burner, which is situated at the furnace to be served. As to this particular appliance there is great divergence of opinion and a greater variety than at any other point of the entire system. It is now generally conceded that the most efficient results are obtained when the coal dust is carried into the furnace in a stream of air, the volume of which is just sufficient to supply the oxygen necessary for its complete combustion; the velocity of the entering jet must be greater than the rate of flame propagation to prevent burning back into the pipe.

This mixture of coal and air must be made in fairly close proximity to the furnace. The reasons therefor are that when this mixing is done there is produced an explosive compound, which it is desired should not be of any greater extent than necessary. The other reason for making the explosive mixture close to the furnace is that there is a tendency for the coal to separate and lose its uniformity of mixture, under which condition it is obvious that part of the jet would be oversupplied with coal, and the other part oversupplied with air. The production of this uniformity is the more important and difficult, and is the rock on which have been wrecked the hopes of more than one enthusiastic experimenter. Various devices have been provided for producing and maintaining the required uniformity of mixture.

* Paper presented at a meeting of the Chicago section of the American Society of Mechanical Engineers.

In the existing commercial installations the fuel is removed from the storage hopper by means of a screw of special design. This screw is placed at the bottom of the hopper and is usually driven by some form of variable-speed device, thereby securing control over the amount of coal extracted per unit of time. It is a well-known fact that the delivery from such a screw is not uniform, the coal being delivered in little heaps and producing distinct pulsations in the furnace. To reduce this effect these screws have been made with a double or a triple helix, in which case two or three charges per revolution are produced in place of one. This is a distinct improvement, of course, but even under these conditions a very noticeable pulsating effect is observed. Devices have been developed for passing this discharged material over a screen, or over a moving disc operated at a considerable speed, the idea being to smooth out the inequalities and produce a continuous delivery of dust. Some of these devices have proved their ability to secure this effect, which is all-important on account of its direct influence on the character of the flame in the furnace. Once established this uniformity must be maintained, and if it be necessary to have the mixer at any considerable distance from the furnace, means must be provided for uninterrupted agitation of the air current in order that the fuel cloud may remain of constant density. This is not a very difficult matter, but is one which must not be overlooked.

Objections and Difficulties.—As is the case with all new things, the early history of the use of powdered coal is replete with accounts of failures, and this has left an impression on the minds of the engineering public which it will take years of successful application to eradicate. The early experimenters did not understand the necessity of fine grinding, and it would seem that they did not appreciate the influence of furnace design upon the temperature of the resulting gases. The coal was powdered sufficiently fine, however, to develop intense temperatures, even though part of the coal was lost by falling to the bottom of the furnace and being thus removed with the slag and ash.

Insufficient combustion space and the ease with which this fuel can be mixed with the minimum amount of air, combined to produce abnormal temperatures and a direct contact of flame and brickwork. The blowpipe effect of the high-velocity jet acted to melt out the brickwork upon which it impinged. A layer of melted lava, formed by the fusing of both ash and brickwork, accumulated in the bottom of the combustion chamber, and, naturally, discouraged those who depended upon this fuel for continuous service.

Later on, difficulty was encountered due to the minute particles of liquid slag being carried on in suspension and deposited upon the tube sheet or water tubes of the boiler, thereby closing up the flame space and putting the boiler out of action. These effects are particularly observable with certain grades of coal, but noticeably absent in others; and only until recently has research work been carried to a point where any knowledge has been obtained of what causes this trouble and what coals are most suitable for firing in powdered form.

Advantages.—Having stated the objections, it is interesting to pay equal attention to the advantages of this fuel. Inasmuch as these advantageous features form the foundation of all discussions of this subject, as well as the impelling cause of all experimental work, I will but merely restate them, depending upon later paragraphs to develop the subject more fully.

From the viewpoint of the theorist, the use of powdered coal forms one of the best methods ever proposed for the promotion of combustion efficiency and commercial economies. In all transformations of energy there is unavoidable loss, and we are not possessed of apparatus which will gasify coal with 100 per cent. efficiency. In the producer there is a succession of losses which reduce the available heat in the gas to a considerable extent, and in the mechanical stoker there are unavoidable losses due to various forms of incomplete combustion. Only in the case of powdered coal is the actual solid fuel both gasified and completely consumed directly within the chamber desired to be heated. With perfect pulverisation the entire mass is burned in suspension, and in actual practice but a small fraction of 1 per cent. is actually lost in the flue dust or slag pan.

On account of the fuel being conveyed into the furnace by the very air which is afterwards to be used in its combustion, and on account of the diffusing of the coal throughout the air in a cloud-like formation, there is a possibility of a mixture which can be secured by no other means. Each particle of coal is surrounded by a particle of air, and on account of the extreme fineness of the particles practically instantaneous oxidation occurs. The result is efficient combustion, and we have to deal only with the effects of the high temperature thereby obtained. That it is now possible to control this temperature while not sacrificing any material gain due to it, is definitely established. Moreover, the definite control of the amount of air per unit of coal permits of the most perfect variation in the results obtained. It would be impossible herein to enumerate in detail all of the means employed to take advantage of the inherent efficiency of this form of firing.

Powdered Coal Fuel in Stationary Practice.—It must be confessed, I think, that steam generation by the use of powdered coal as a fuel is still in the experimental stage, and here, if anywhere, will it meet severe competition. That steam can be efficiently produced in this way is unquestioned if merely combustion and evaporation are considered. Whether it can be generated more economically than it is at present by plants with the best mechanical stokers, still remains to be commercially proved, and, even with powdered coal, gas analyses better than 16 per cent. of CO_2 are not developed. With the mechanical stoker the CO_2 can be maintained around 14 per cent.

With powdered coal the loss in the ash pit and in the flue does not exceed 1 per cent., and with the best mechanical stokers this loss will not exceed 2 per cent. of the coal fired. A possible advantage of 2 or 3 per cent. in combustion efficiency in favour of powdered coal is offset by the cost of fuel preparation. It is not reasonably to be anticipated that we can get better than 96 per cent. efficiency, and this is a figure which can be obtained by the mechanical stoker. I foresee, therefore, a hard fight for powdered coal in stationary steam-boiler practice.

Powdered Coal Fuel in Locomotive Practice.—It is in cases such as the locomotive that powdered coal shows most favourably. Here we have not only the simple problem of combustion efficiency, but a long list of related conditions that are affected thereby. I can do no better than to quote the summary of the report of the standing committee of the Railway Fuel Association. Summing the results that are being obtained in locomotive service these may be stated as: (1) Smokeless, sparkless, and cinderless operation. (2) Maintenance of maximum boiler pressure within a uniform average variation of 3lbs. without popping. (3) An increase of from 7½ to 15 per cent. in boiler efficiency as compared with burning lump coal on grates. (4) Saving from 15 to 30 per cent. in fuel of equivalent heat value fired. (5) Enlarged exhaust nozzle area, resulting in greater drawbar pull and smoother working of the locomotive. (6) Elimination of ashpit delays, facilities, and expenses, and reduction in time required for, and ease in, firing up. (7) Maintenance of a relatively high degree of superheated steam. (8) No accumulation of cinders, soot, or ashes in the superheater or in the boiler flues, smokebox, or on the superheater elements. (9) No punishment or overheating of the firebox, new or old sheets, seams, rivets, patches, bolts, stays, or flue beads. (10) Elimination of arduous manual labour for building, cleaning, and dumping fires, and for firing. This feature would appear to be quite advantageous, due to difficulty experienced in holding satisfactory labour on this class of work at the rates usually paid. (11) Avoidance of expense and annoyance in providing various sizes and kinds of fuels. (12) Elimination of front end and ashpan inspection and special fuels, firing tools, and appliances for building fires, and for stoking and cleaning them.

The committee is of the opinion that the effectiveness and utility of the use of fuel in pulverised form has been demonstrated from the past year's development, and that the progress in the use of this method of stoking and burning bituminous and anthracite coals and lignites for generating power, heat, and light on railways will be quite marked from now on.

The constantly increasing cost of railway fuel at the mine; the scarcity of fuel oil; the domestic and export demand for the larger sizes of coal; the prohibitive cost for briquetting

the smaller sizes of coal and of lignite for railway use; the payment of labour on the run-of-mine basis for mining bituminous coals; and the necessity for eliminating smoke, sparks, and cinders, will all tend towards the inauguration of this practical means and method for increasing the efficiency of steam-boiler operation, which to-day affords the greatest opportunity for improving locomotive and power-plant costs and performance, and for changing public sentiment by smoke abatement.

Ash Fusibility.—A phase of the combustion problem both in connection with powdered coal and mechanical stokers, which is but now receiving adequate attention, is the study of the temperatures and conditions under which ash will melt. Engineers have always recognised the fact that certain coals were greater clinker producers than others, and this was laid at the door of the sulphur content. Recent experimental work, however, has shown that the sulphur is not the controlling element, although the exact causes are not yet sufficiently well known to be definitely stated.

Coal ash will melt at temperatures between 2,200° and 2,700° Fah. Furnace temperatures in commercial practice run between 1,800° and 2,800°, so that it is possible to secure coals the ash from which will pass through the furnace without fusing. Under these conditions absolutely no clinker formation is encountered, and the coal is rated as satisfactory from this standpoint. In exactly the same furnace another coal will clinker badly and give trouble. There is no hard and fast rule, therefore, which can be stated for the selection of a coal.

The temperature obtained in service, which is a function of the rate of combustion, the amount of excess air, and the proportions of the furnace chamber, must be determined, and analyses of the fuel made to determine whether or not it will be suitable under the given conditions. Like many other scientific investigations, the value of a few dollars spent in this manner is not always appreciated, and the user will tolerate the formation of clinkers for months before he turns to another source of coal supply. When he does so, he may or may not solve his problem, and it becomes necessary to purchase and consume a variety of coals before one is found which is suitable to his needs.

In powdered-coal work, with the more precise and scientific manner of the combustion process, the necessity for proper knowledge of ash fusibility is greatly increased. The day is rapidly approaching when the burning of coal will be considered a precise scientific chemical reaction, in which the elements are supplied with exactness and understanding, and the result obtained, corresponding in definiteness to the precision of the mixing process, will be made to conform exactly to the requirements of the service.

The Commercial Testing and Engineering Company has determined that washing a dirty coal has no effect on the fusing point of the ash, so that mere ash content is not the determining factor of desirability when considering a coal for pulverisation. The importance of this preliminary investigation can scarcely be overstated. Assuming a malleableising oven, wherein the temperature does not exceed 1,800°, it is quite obvious that this is below the melting point of ordinary ash, and aside from the objection to a large volume of ash, any coal can be used.

Considering a furnace of higher temperature requirements, such as a billet-heating furnace where, say, a temperature of 2,300° is desired, it is obvious that a coal fusing at 2,500° would be entirely satisfactory, whereas one fusing at less than 2,300° might cause clinker formation. In the case of still higher temperature work only those coals which have the highest fusing point could be used, unless ample provision were made for the accumulation of fluid ash.

Conclusion.—My general conclusion as to the future of powdered coal as a fuel is briefly this: Powdered coal is radically different in its physical structure and method of handling from any other form of coal heretofore commercially used. Having marked characteristics it will fit into certain cases with extreme acceptability, and will probably prove just as undesirable in certain other cases. Probably the most important difference is the burning of the actual solid fuel directly within the chamber and in direct physical contact with the metal to be heated. There is, of course, an appreciable amount of incandescent carbon in the furnace at all times, and this solid fuel is emitting radiant heat in close proximity to the furnace contents. A large amount of the radiant energy is therefore directly utilised, which is not the case when coal is gasified in a detached chamber. I cannot but conclude, therefore, that the success of powdered coal lies in its adaptability to the special furnaces of the metallurgical field, and in those cases similar to the locomotives, where there are other and weighty considerations in addition to the actual relative increase in combustion efficiency.

THE 1917 MARTELL SCHOLARSHIP IN NAVAL ARCHITECTURE.

A SCHOLARSHIP designated the "Martell Scholarship in Naval Architecture" will be offered for competition by the Council of the Institution of Naval Architects, who have been appointed administrators of the fund available for providing the scholarship. The scholarship is of the annual value of £100, and, subject to the following conditions, is tenable for three years. (1) Candidates for the scholarship must forward a written application to the secretary of the Institution of Naval Architects, 5, Adelphi Terrace, London, W.C., to reach him not later than January 15th, 1917. (2) Candidates are not to be less than 18 nor more than 21 years of age on March 1st, 1917, and must at that date have been continuously employed for at least two years upon naval architecture or marine engineering. (3) The scholarship will be awarded in connection with the competitive examinations for scholarships, studentships, &c., to be held by the Board of Education in May and June, 1917, in the following subjects: Naval architecture, pure mathematics, applied mechanics (materials and structures), and either (*a*) applied mechanics (machines and hydraulics) or (*b*) heat engines. For information as to the exact dates of these examinations, and particulars regarding them, application should be made at once to the Board of Education, Whitehall, London, S.W. Candidates residing in Scotland or Ireland should apply for information as to the examinations to the Scotch Education Department, Whitehall, London, S.W., or to the Department of Agriculture and Technical Instruction, Upper Merrion Street, Dublin, respectively. (4) In addition to the above subjects of examination the candidates will be required to furnish, not later than January 16th, evidence that they have passed some literary test in English, such as would be covered by the Oxford and Cambridge local examinations, a recognised school leaving certificate, or a University matriculation examination. (5) No candidate will be appointed to the scholarship until he has produced a certificate of good character and of time of service from his employers and a certificate of birth. (6) Each candidate appointed to the scholarship will be required to undergo a three years' course of study in naval architecture in such university or college (combined, as far as possible, with a practical training in a shipyard or marine engine works, during the college vacations) as he may propose and the Council shall approve. (7) A report is to be sent in to the Council at the end of each session of study by the holder of the scholarship on the progress made and the results of examinations attended. This report should be endorsed by some responsible member of the body under whom the holder is working. If the progress made should, in the opinion of the Council, be unsatisfactory, or if the holder of the scholarship should, in the opinion of the Council, cease to comply with any of the conditions of tenure, the Council will determine the scholarship and may fill the vacancy thus arising. (8) This scholarship may, at the discretion of the Council, be withheld from any student who, in the opinion of the Council, does not stand in need of the financial assistance of the scholarship to enable him to pursue the course of studies prescribed by the regulations. Each candidate will be required to produce evidence that without the assistance of the scholarship he would not be able to follow the prescribed course of studies. (9) All communications with respect to this scholarship should be addressed to the secretary of the Institution of Naval Architects, 5, Adelphi Terrace, London, W.C.

ACCIDENTS AT BLASTFURNACE PLANTS.*

THEIR CAUSE AND PREVENTION.

BY FREDERICK H. WILLCOX.

IN attacking the accident problem in a blastfurnace plant, it should be realised at the outset that it is impossible to prevent all accidents. On the other hand, it is not necessary to inaugurate a complicated and expensive campaign in order to remove many of the hazards surrounding the workmen. The ordinary methods employed every day in keeping production up to the required standard, maintaining equipment, guarding against incompetence, or enforcing discipline can be profitably applied to avoiding accidents, carelessness, awkwardness, or unnecessarily hazardous conditions.

The chief causes of accidents at blastfurnace plants in order of their importance are as follows: (1) Hand labour, (2) hand tools, (3) flying and falling material, (4) falls of person, (5) burns from hot metal, (6) machines and machinery, (7) cranes, hoists, and rigging, (8) hot water and steam, (9) burns from cinder, (10) flames, (11) railroads, (12) asphyxiation, (13) slips, (14) illness, including intoxication, (15) hot flue dust, (16) electric machinery, (17) explosives, (18) fighting and playing. If burns from hot metal and burns from cinder are grouped together they rank third. Hand labour and hand tools cause over 40 per cent. of all accidents; if flying and falling material and falls of person are included, over 60 per cent. of all accidents are represented; and if burns from hot metal and cinder are added the total represents approximately 75 per cent. of all blastfurnace accidents. Machines, cranes, hoists, railroads, explosives, and other obviously dangerous factors represent a comparatively small percentage of the total. It is apparent, therefore, that the number of injuries can most easily be reduced by eliminating the commonplace dangers to which the majority of the workmen are daily exposed.

The foremen, who are in close daily contact with the men, are familiar with plant conditions, and who have supervisional authority, are naturally the men best fitted to take the responsibility for safety work. When properly supplemented with the work of suitable committees and with the co-operation of gang leaders, inspectors, and others, the efforts of the foremen cannot fail to bring about a noticeable reduction in the number of accidents. On account of the part played by foremen in safety work in a blastfurnace suggestions pertaining to their duties come first in the order of importance. Do not place a slow, heavy man where a quick, active one is required, or a slow-thinking man where a quick-witted one is required. Moreover, do not keep on the same job a man who gets hurt frequently in that occupation unless the labour supply is inadequate or men cannot be shifted. When a man is employed or put to work on a new job instruct him as to his work and how to avoid accidents, warn him of unusual or obscure danger, and then put him under the charge of the gang leader. You should consider yourself personally responsible for accidents that happen to your men from their ignorance of danger or of safe methods. Therefore watch for dangerous practices, ignorance, lack of skill, and carelessness, and take the necessary steps to correct faults when first noticed. Most men can be taught and encouraged to use proper methods of work, but when necessary press on the men by admonition, warning, suspension, or discharge, your attitude against carelessness or indifference. Drill your men to report immediately when injured, however slightly; send an injured man to the doctor or first-aid man, and then investigate the accident at once and discuss it with the sub-foreman and workmen in order to bring out clearly the cause and impress it on their minds.

Be watchful about the furnace. Gas may be escaping in many places and may kill you before you know it is present, the furnace may slip, the bosh or hearth of the furnace may break out, a tuyere may burst, or a blowpipe burn through, or there may be an explosion. Keep out of the cast house except when your work calls you there. The furnace crew can sometimes tell when these things are about to happen by signs with which they are familiar; at times they happen without warning. Stay at your own work and be safe. Keep away from the bottom of the dust catchers, from under the down legs of gas mains, and off of manhole covers of gas flues. Do not stand near iron and cinder ladles while they are being filled, shifted, or poured. Do not go near a cinder granulating pit while it is in use, and do not stand about gas burners or air doors of stoves. Never go on top of a furnace or gas washer unless under the direction of the foreman, or accompanied by some one. The tops of boiler settings, gas engine basements, skip pits, and ore bins should be avoided unless your work takes you there. Before you begin work in such places, or in any place where there is a possibility of danger, wait until the foreman has told you that it is safe to go. Satisfy yourself that the place has been made as safe as possible. Never look in the peep holes of the tuyere stocks unless it is part of your duty. Always watch when passing near the furnace. Remember that frequently it is impossible for the furnace men to tell when the furnace is going to slip.

Do not refuse to use safeguards, do not ignore rules and orders, or disregard danger signs. There is a reason for each and every one. Be sure to report every accident, even the slightest burn, cut, bruise, puncture, or substance in the eye, as this may prevent a trivial hurt from becoming a serious injury. Do not set bad examples by bravado, thoughtlessness, or negligence for less experienced men to follow. Use commonsense as well as foresight and watchfulness.

Acquaint labourers and new men with the possibilities of slips, gas, breakouts, and bursting tuyeres. If you can show them how to be less clumsy in handling tools do so, because awkward men may injure others as well as themselves. If you see anyone doing something that is dangerous, or standing in some place where he might get hurt, tell him of the danger. If a man's clothes catch on fire, do not let him run. Put the fire out with a hose, or roll him in sand and smother the fire by throwing sand on it, or wrap him in a blanket or coat. If a man is gassed or receives an electric shock, get him into fresh air, notify the foreman, and give him artificial respiration at once; loosen his clothing, take any tobacco out of his mouth, and keep him as warm as possible.

Always wear clothes made of wool or hard jean cloth, if possible, and especially avoid greasy clothes, as they will readily catch fire. Wear stout shoes having thick soles and without cracks or holes, that are not too low and fit tightly about the leg. Wear goggles or a mask to prevent injury when handling hot metal or cinder, breaking scraps with sledges, or turning hose on hot material. Never wear ordinary gloves or hand-made hand leathers in handling jagged pieces of scrap. Leathers or gloves with a safety spring in the back are the only safe ones, as the scrap will frequently catch the glove or leather and may cause a serious sprain or fall.

When breaking runner scrap, slag, lumber, test pieces, &c., with sledges, use judgment in blocking up the pieces before breaking them. The closer the material is to the floor, the less probability there is that it will fly in breaking. When barring scrap, plates, or other objects, be sure that the point of the bar is firmly engaged, or that the bar will not slip off the block before you lift or put your weight on the bar. Keep your working place cleaned up. Bars, drills, and long-handled tools should be kept where they will not fall and injure any one, by preference in a tool rack. If they are leaned against the wall, place them so they cannot easily be knocked over or fall down. Don't leave tools where men can stumble over them. Remove burned drills and bars promptly. Watch out for hot bars, and don't throw bars without looking to see whether someone may be hurt by their rebounding. Be careful when the cast house is full of steam; feel your way, do not attempt to go quickly.

When a blastfurnace is being blown in or blown out, banked, stopped for a time, or started up, it is more dangerous than in regular running. At such times do not rely upon your own knowledge of furnaces, but follow every direction of the foreman strictly. Do not do any of the routine duties about the stoves, dust catcher, bleeder, cinder notch, tapping hole, or tuyeres except by direction of the foreman or blower.

Don't go on the bustle pipe unless you notify the stove tender, keeper, or blower. When you have to work where you can smell gas, take frequent spells in fresh air and work with another man. Do not stay where there is gas unless

* From Technical Paper No. 136, issued by the United States Bureau of Mines.

your foreman knows the condition and that you are there. Do not rest or stand under, near, or in front of blowpipes or tuyeres, as they may burst or burn through and throw metal, cinder, coke, or gas over you. When you know that the furnace is hanging, keep under cover, and warn others. Keep away from the bottom of dust catchers, stove burners, down legs, and manholes of underground flues at such times. In going to and from work avoid going under cranes carrying loads or under skip inclines, or through stock houses, boiler rooms, or places where you are unfamiliar with the work which is being done there. Do not try to do work other than your own about the furnace unless you are familiar with the work or have been ordered to do it. Especially do not try to help the hot-blast man on shut-downs or on work with the bleeder, mixer valve, or any regulating part of gas or blast mains unless everything you do is specifically directed by him. Many accidents have been caused by misunderstanding what some one else was doing.

Always use every safeguard provided—goggles, masks, shields, safety hand leathers, tongs, and gloves. They are provided to prevent injury to yourself, and men at other plants use them. Refusing to use them is not a sign of bravery or of familiarity with your work, but rather of foolhardiness and ignorance of the danger.

Do not drive the tapping bar through the skull in the tapping hole, or go on the last spell on the drill before you have placed the splasher and put a shield in front of the tapping hole, or a cover plate or sheets over the trough, in front of the splasher except under unusual circumstances. When it is necessary to pull the tapping bar out, don't hold on to the "welshman." Lay a bar across the runner to support the tapping bar while driving it out; the molten iron may rush out unexpectedly and burn you.

Do not stand in front of the iron notch when opening it; work from the side as much as possible, even on the first spell, and keep your feet out of the trough. Be especially careful when working on a short, green, hard, or unusually long hole. On changing turn, the keeper going off duty should inform the one coming on as to the condition of the tapping hole. If the hole has been working short or badly, and has not been taking the clay, the keeper should inform the other keeper and tell him how much clay was used on the last stop. His work will then proceed intelligently. Do not cast until the skimmer trough, runners, shutters, and spouts are dry and warm. Clay, sand, loam, or coke dust in the runners must be dry to avoid boils of molten iron. Do not leave pieces of cold scrap in the runners or place damp sand against the shutters or gates. Don't let pieces of wood get under the skimmer dam or drain gates and bank up the drain or punch-out gates on the outside with dry sand. In filling the mud gun before a cast, only one man should do the work if the clay is being fed at the funnel, because if two men are used, one to operate the plunger and one to feed the clay, one of them may be caught by the plunger. In loading clay at the funnel, do not push it down with your foot; use a stick. However, the gun can be loaded as well and more safely by putting clay in at the nose of the gun with a rammer. When the gun is loaded put about 3in. of dry sand or ground ganister mixed with tar or black oil in the nose, removing enough clay to give room. Wet or sloppy clay may cause an explosion when it comes in contact with hot iron. Do not wet the nozzle of the mud gun. Daub it with black oil after casting, while it is still warm, and again just at cast time. This will help keep it from getting wet and will prevent a "shot" if the nose of the gun is placed in the hole against a stream of molten iron. Oiling the nose of the gun is better than warming it, becaue if the nose is heated too much or too long, the clay will become dry and stiff, and may cause a short hole. If heating the nose is preferred, pouring one or two hand ladles of cinder over it should be sufficient.

When casting do not use cold or wet bars to poke out sand, clay, or loam in the runners or gates, or to break a path for the iron. Lift the punch-out or drain gate slowly to avoid a rush of iron, which may cause boiling, and be sure the punch-out bar is warm. Before turning the iron into a ladle see that the ladle is spotted and is all right. Do not fill the ladle within more than 8in. or 9in. of the top, as the iron may be spilled in shifting it. Do not throw large pieces of cold scrap into the ladle before or during the cast, as it may cause boiling or an explosion of the hot metal. It is safer to fill the ladle nearest the furnace first and finish the cast in the ladles at the lower end, for several reasons. One reason is that the gates may be lifted quickly and the operator go away instantly. The gates should be equipped with a safe controlling device. If the iron is run to the bottom ladle first, be sure that all shutters are dry; if to the top ladle first, be especially sure the sand at the gates is dry. When using the pricking rod on an obstruction in the tapping hole, do not throw too much weight on the rod if standing close to the trough. Be sure that the hand ladles and chills for samples and pig-machine wheels are dry. Do not cross iron or cinder runners during a cast except where necessary, and watch your step very carefully; if you have to go in front of the iron notch, get across quickly. Do not step on the crust of hot cinder. Do not flip wet clay into hot iron to annoy or tease a fellow-workman. It is an extremely dangerous practice. Also in stopping the tapping hole, be cautious when placing the mud gun in the hole. Unless the cinder and iron in the trough lays away from the hole, drain the trough before putting the gun in. Do not put the gun in the hole against a stream of iron unless the nose is warm and dry, as the iron may explode. After the gun is clamped, turn the steam on by the valve at the column, or by means of a long hook open the three-way cock on the gun. There is danger of gas bursting out or cinder being thrown back when the first clay is shot in. Care must be exercised in stopping the hole after the first shot, as the pressure in the furnace and the suction of the plunger may throw the clay back in the barrel of the gun and a burst of gas or slag follow. It is safer to feed the clay into the gun with a shovel rather than to stand close to the hole and trough, unless one is expert at throwing the balled clay into the funnel from a safe distance. As stated before, use a stick—not your foot—to poke clay down into the funnel. While stopping the hole do not stand so that your weight is on the sheets covering the trough, and watch for the exhaust steam. Do not put the wind on until the hole has stopped taking clay freely, and after the hole is stopped leave the gun in it with steam on until the clay has set; this may prevent a breakout at the tapping hole between casts. If men are changing tuyeres or plates, never throw or turn water into the funnel of the mud gun or use wet clay before the hole is entirely stopped, as gas may blow out on the tuyere men. Step away from the gun for a moment when shooting water into the hole.

Never tighten the keys on the tuyere stocks or caps, or take up slack on the bridles when the blast is on unless you are directed to do so by the foreman. Watch for tight bridle springs or split stock hangers, and don't screw up the nut on the bridle until the spring is tight. Do not start to loosen the monkey or stock bridles, hangers, keys, or caps until the blast is off and the gas is drafted back. Wear goggles when watching the peep sights during a cast or check, and do not open the peep-sight plug until you are sure no one is in line with it. Don't try to blow coke out of the eyesights until the blow pipes have had time to cool. Know where the hose and water valves are situated in the cast house, as they are needed quickly at times. When playing the hose on tuyeres, blowpipes, or the furnace jacket, stand behind a column as much as possible, or to one side, as they may burst or burn through. In case a tuyere bursts or a blowpipe burns out do not work about them unless thoroughly familiar with the danger. Work to one side as much as possible when dropping blowpipes, claying up, and changing tuyeres, as cinder, coke, or gas may blow out. The tuyere opening should always be firmly plugged with clay as soon as the blowpipe is dropped. Never work about an open tuyere or plate when water or wet clay is being put in the tapping hole. Watch for hot bars, blowpipes, and scalding water or steam. Do not put up the blowpipes after a shutdown until the foreman orders you to, for unless the blowing engine is turning over it might cause an explosion. Don't look into a blowpipe when cutting out clay after a stop.

When plugging the cinder notch, wear goggles or a mask and long leather gloves; be sure of your footing, and always use the shields provided. Work from the side of the cinder notch as much as possible when opening it, and when break-

ing cinder in the runner during a flush keep out of line with the cinder notch and be careful the cinder does not splash on your feet. Cinder will splash farther than iron. Keep as far away as possible when throwing coal in the cinder runners. It is just as well not to throw coal into stiff cinder as it does not greatly help matters.

Do not throw damp or wet rubbish in the cinder ladles, and always examine them for water or dampness and dry them out with cinder before flushing or casting, because a damp ladle may boil or explode when being filled. Keep away from the granulating pit when the skimmer trough is being drained or when you think iron is coming over the cinder dam. If it is necessary to plug a cinder ladle with clay, always place a sign or station a watcher before going into the ladle. Be sure there is no one in a car or ladle before throwing rubbish into it.

Be prompt to report anything abnormal or unusual about the furnace—for instance, the blast pressure becoming high or low; hanging, tightness, or slipping of the burden; cold or dirty cinder; sloppy, dead, or leaking tuyere; gas lighting on the bosh or about the mantle; hot spots on the shell; delays in filling the furnace or in spotting iron or cinder ladles; wind and gas leaks; or signs of a break-out, such as steam or gas coming from about the jacket, columns, or pavement, the water getting hot or steamy in the discharge from the hearth or bosh jacket or on the jackets, or the pavement or columns getting unusually hot. Especially, report promptly any signs of the cooling water supply becoming slack. Neglect of these points oftentimes leads to unnecessary hard work and danger from messes, breakouts, slips, burned tuyeres and blowpipes, or explosions.

In putting water in the skimmer trough do not stand near by with a short nozzle. If the water strikes hot slag, the steam may scald you, and if it strikes a pocket of hot molten iron there may be an explosion. It is safer and just as effective to use a pipe, 15ft. or more long, turned down at the end. If it is necessary to break up crusts or skulls in the trough before turning water on, don't use a cold or wet bar. When handling hot scrap or slag use tongs or a hook whenever possible, and be careful in breaking or barring slag and scrap to avoid flying pieces, falls, or dropping material on to your feet. Before throwing scrap or cinder into a car be sure there is no one in it and that the pieces do not project over the end or sides of the car where they may fall or be pushed off.

Be careful that the gas or blast is not turned into or gas drafted back through a stove that is being cleaned. Do not open or close any doors or valves or remove any signs or locks on such stoves until the foreman has told you to do so. Before turning gas into a stove, warn any well-bottom cleaners working about the doors. If you think that the stove is not hot enough to light the gas, put a large bunch of burning waste at the gas door or provide other means to ignite the gas. Don't stand by the burner after turning gas into the stove; step away quickly. At times the gas will not light until it reaches the top of the well or combustion chamber, and it is then likely to light explosively and puff out through the burner and air doors. Be especially careful when you are turning on gas from a furnace just blown in or from one shut down on account of leaky tuyeres, coolers, bosh plates, cinder monkey, &c. In case of doubt always use burning waste; don't let the stove fill with gas and then try to light it. If the stove does not light, shut the gas off and start over again, using burning waste.

Before you blow off a stove, warn men to keep away from the blow-off valve, and especially warn them away from the blow-off door if the stove is being shut down for a leaky tuyere, as the gas may be very explosive. Be sure that the blast is on the new stove before shutting the cold-blast valve of the stove being taken off. Don't let the hot-blast valve drop sharply on to its feet, and don't let the blast slam the chimney valve into place; set the valves easily by hand. Open the cold-blast valve slowly to avoid racing the blowing engines.

In case of the blast stopping unexpecedtly from any cause shut the mixer valve on the by-pass at once, then close the cold-blast and hot-blast valves as soon as possible. Never forget to close the mixer valve before checking or shutting down the furnace, beginning a cast, or stopping the blowing engine. To forget to do this may cause an explosion that will wreck the mains and engines. When it is necessary to take the stoves off during a shut down to change bronze, or for a short stop, be sure the burners are closed tightly. When ready to start the furnace and bring the gas down, never turn the gas into the stove until the blower has given the signal. Be sure that the explosion doors or bleeders on the gas mains or dust catcher are closed during a shut down; if any air gets into the mains there is always a chance of an explosion. Always follow the instructions of the blower in handling the top bleeder during a shut-down. Many serious furnace accidents are caused by operating bleeders and gas valves other than in the way ordered. The least change from orders may cause a terrific explosion. If the gas is wild in drafting it back in one stove at a shut-down, draft back through an additional stove at once.

Keep away from the dust legs and manhole covers on gas mains, from gas burners and air inlet doors, when the furnace is sticking and liable to slip. Be careful when you open an air door to see how the gas is burning; if too much gas is turned on, or if the checker work is dirty, the gas may flash back into your face. Keep and warn others away from these places. No one should handle burners, doors, or valves unless directed by the stove tender. Do not tighten any thumb or other nuts on doors or blow-off valves when the stove is on blast; you may be killed or injured by the bolt breaking. Watch the water on the hot-blast valve and seat, because water leaking into the stove may cause the furnace to slip or get cold; it will then be more dangerous. Report any gas leaks about the burners or mains; do not let them leak unnecessarily. When the millwright is examining the chimney valve for leaks do not change the stove from blast to gas. When the hot-blast valve and seat are being inspected be sure the chimney valve is kept open and that the gas is turned off. Before entering a stove to clean it, lock the cold-blast valve and gas burner shut, fasten the chimney valve open, and either block the hot-blast valve in its seat or disconnect the cable from the stem, or lock the windlass, and attach danger tags; be sure these things are done. Stop any leaks about the burner with clay, as even a small leak may allow considerable gas to drift into the stove. It is always safest to close the burner door, but if this cannot be done for any reason, turn the burner on its seat, away from the door or seal it off with a blank. When ladders must be used to get into a stove through the dome manhole do not try to carry tools up or down the ladder, use a hand line. Keep away from the well of the combustion chamber, and do not sit on the bridge wall between the well and the checkerwork; the wall may give way. Boatswain's chairs for cleaning, tearing out, or repairing the well lining should be supported by tackle attached to the top of the stove shell when possible, and the chair, rope, and tackle tested to double a man's weight before use. Anyone working in a boatswain's chair should wear a life belt attached to the chair-sling block. Do not use a torch inside a stove; use an electric light on a standard insulated extension cord and have an electrician make all connections. When it is necessary to clean checkerwork from the bottom or to clean out under the arches keep under the arches as much as possible to avoid bruises from falling brickbats, clinkers, or tools. It is best never to enter the bottom until everyone is out of the top. Always wear goggles when inside a stove and do not remove the locks from the valves until everyone is out and the manholes are closed. In cleaning flue dust from the bottom of a stove be careful to avoid burns; the dust is usually hot and easily runs into one's shoes. Notify the stove tender, before opening the cleaning, air inlet, or blow-off door to clean the well from the outside, and have him turn the gas off enough to avoid any danger of flame puffing back through the door at which you are going to work. In case the furnace is hanging stop work until it slips and keep away from the cleaning door. In loading barrows with hot cinder or dust do not fill them so full that they will run over; handle them carefully, and warn others to keep out of the way. Bars and cutters used in cleaning wells should be handled with crossbars when withdrawing them from the stove. Keep away from the doors when gas is being turned in the stove.

Empty the dust catcher regularly; if you let it get filled, and the furnace slips, there may be an accident. Notify the

foreman when the car is full and if the car is not moved promptly and an empty one spotted. Never dump the dust catcher when the wind is off the furnace or when the furnace is hanging or liable to slip unless you are doing it under the orders and directions of the foreman or superintendent. In dumping dust legs, dust pockets, or dust catchers be sure there is no one underneath to get burned, and warn men against approaching, as the dust may fly and burn them. Be careful in cleaning up dust and never step on it, because it will run like water when hot, and burn you severely if it gets in your shoes. Be cautious in playing a hose on hot dust, as it sometimes explodes or flies. Do not clean up under the dust catcher unless you have notified the foreman and he has told you to go ahead; the bell may be forced open by a slip or by being overweighted and the dust may burn you. For the same reason never go into a dust car after it is spotted under the dust catcher; pack the doors before the car is placed. Turn the water on full before you open the bell, and water the dust thoroughly when dumping the dust catcher. Don't fill the car with hot dry dust and then turn the water on; it will soak down slowly, and the contents may explode. Always place a card on the car so that the unloaders will know they are handling flue dust.

Rod the furnace regularly, and in case it is hanging or stiff report to the foreman promptly. If anyone is working in the skip pit, on the skip incline, hoist, or skip, don't move the skip, except under direction and after giving warning. If an oiler or handy man is working on the sheave wheels, bell rods, hoppers, distributor mechanism, or bell-rod cylinders, do not lower the bells except on signal from those on top. Never start the skip or hoist cage until you receive the proper signal, unless you have all regular charging operations in sight, and then signals are not required. When the blast is off, or when the furnace is shut down and men are working about the top or bottom, do not fill the furnace or lower the bells without warning the men away from the tuyeres and hoppers on top, and then only under the direction of the foreman. If the furnace is being shut down or if it is working irregularly and stops taking charges on account of hanging and slipping, do not put wet ore on the bell; at many plants it is considered dangerous to dump wet ore when the furnace is low. Report anything about the skips, bells, or indicators that does not seem right, such as skips striking the bumper blocks too hard, slack or frayed cables, irregular, slow, or quick movement of the bells, or water in steam lines. By early notice an accident or possibly a hazardous delay may be avoided. Never let anyone go up the skip incline to the top alone.

Scale-car operators should watch for stock-house cleaners or others crossing the track and should always have the car under control. Watch out for overhead obstructions. Let the furnace millwright or electrician do all repair work on the car. Be careful not to leave ore or stone on the edges of the chutes; many accidents are caused by stock falling from the chutes. When barring or punching at the chutes or doors of the bins be careful to avoid a rush of ore or stone falling on your foot. Do not open the door of the nearly empty bin or get under it just as the car doors are dropped on the trestle; the material may easily fall through and bruise you, or if it is flue dust or sinter, burn you. Wear goggles when the coke is very dusty or when breaking ore or limestone. If steam is used to thaw ore in the bins or piles be sure that the hose is strong and in good condition. See that no one is in line with the nozzle when you turn on the steam. If gas is used, see that it stays lit and that a pocket of gas does not accumulate. Do not light gas by hand with a match, use burning waste, placed on the floor or in the chute.

Most accidents with ore buggies happen from catching the fingers between the buggy handle and a column, wall, or other obstruction. Watch out for this and use safety handles. Be careful not to let the buggy leg come down on your heel, or to run the wheel over someone's foot. Never race with a buggy, you may easily lose control of it and receive a wrench, strain, or bruise. Watch that your fingers or feet do not get caught between a lump of stone or ore from the chute and the buggy or floor. Don't undercut an ore or stone pile, or let the stock lodge above you, keep it knocked down with a bar. Never stand close to the elevator pit as the cage comes down, ready to take the buggy off the instant the cage comes to rest, as many men have had their feet crushed in this way by getting them caught between the cage and the floor sill. Don't try to get on the cage before it has come to rest, or after the signal for hoisting has been given.

When it is necessary to clean the skip pit, notify the skip operator and do not go into the pit until he tells you to. Avoid walking under bin doors and chutes. Keep off the scale-car track and watch for the car when crossing the track. Don't stand on the track when signalling the car operator. Be careful that your bar does not touch a third rail or trolley wire. It is best not to ride on the scale car, and you should never jump on or off the car when it is moving.

When you enter the motor-house or hoist-engine room notify the skip operator, both on entering and leaving. Keep away from the cast house and stoves unless you are required to go there to help. Report all bad places to the foreman, such as dark corners, overhead obstructions, poor track, holes, and unsatisfactory bin doors. Be sure to report every injury, as even a slight injury if neglected may have serious or fatal results. Even a bit of coke dust may seriously injure the eye if not taken out right away. If a man receives an electric shock free him from the source of current, being careful not to get a shock yourself, give him artificial respiration at once, and send for the foreman. Similar first aid is needed if anyone becomes gassed while working on top.

On hand-filled furnaces top fillers should remember not to step over trap or lift doors at the top of elevator shafts while the elevator is running.

The safety of many men about a furnace plant depends indirectly on the care and interest the stock-house crew take in their work. Careful weighing, regular charging, reporting any difference in appearance or quality of coke or limestone, and constant watching of the movement of the charge in the furnace will prevent many slips, messes, and dangerous work at the tuyeres, tapping hole, and furnace top. Watch for the larry car, locomotives, and cranes, and do not go under the ore bridge just before ore is dumped into the bins. Do not jump on or off moving cars. Never sit on or near the track or bridge rails to rest; find a safe place. When you hear the warning whistle at the furnace get out of the car at once and under shelter as it means the furnace is hanging and may slip. When ore is being dynamited and a warning is shouted, get under cover and stay there until material has stopped falling. Do not try to jump across the bins from rail to rail; use the cross-overs. They were put there to use, and the minute saved by not using them is worth less than the good example set by using them.

Do not use a pole in spotting cars with a transfer car or locomotive on an adjoining track, use a cable with safety hand locks. If there is no cable and a pole must be used, stand on the same side of the pole that the coupler of the car is on. Be careful in pinching cars on the trestle, you may fall and receive a severe injury. Pinch a car the way the foreman has shown you, and report pinch bars with smooth heels or dull points to the toolman or foreman. A pinch bar fitted with a disc and toolsteel heel lessens the danger of injury. When turning on a steam jet to thaw ore see that no one is in line with the jet; use a clamp to hold the nozzle, and avoid working with worn hose. Watch that cinders from trestle locomotives, or hot coke, do not start fires in the coke bins or walks.

It is dangerous to open drop doors on loaded cars unless you know how. Do not try to do it until you have been shown. Before getting into a car to unload it, or crawling under a car to work on the drop doors, make sure, by asking the foreman, that the car will not be moved. Wait until the doors are dropped before going on top of material in cars to be unloaded. When unloading hopper cars, do not stand over doors or on the edge of the material; it may slip and carry you down into the bin where you may be suffocated or severely injured. Obtain a firm footing in the bottom of the car between the doors, or be sure of a firm hold on the side of the car. By all means wear a belt and safety line, if these are provided. Do not undercut material any more than is necessary and watch that the lumps do not catch you. Be very cautious in opening the doors of cars loaded with flue dust; if dry, it will fly out. Avoid stepping on flue dust in cars, for even apparently wet dust may be dry and hot

beneath and cave when you step on it. Always get out of a car the same way you get in; do not crawl out through the doors in the bottom of the car.

Before you drop material into empty or nearly empty bins notify the stock-house crew so they can keep clear of falling material, and be sure that the bin doors are closed. In poking ore in bins and chutes see that you will not get caught in case a fall of ore catches the bar. Never go into any bin to shovel material or to clean the bin unless you have a belt with a life line attached to a girder or tie. Use a flag or track torpedo to protect the bin you are working in, or ask the foreman for a watcher to hold the line and warn men not to dump material in the bin or run cars over it.

Stay out of cast houses, pig machines, boiler houses, and other places where your work does not require you to go, and keep away from iron and cinder ladles when they are being shifted. Whenever possible, keep from under cranes in operation. Always warn the crane man before beginning to clean the tracks about the granulating pit, as he may accidentally drop some hot slag over the sides of the car unless he knows you are beneath, or scalding water may run from the grab bucket as it is carried over your head. Be careful in cleaning up about a loaded cinder car, as steam and scalding water may escape suddenly from a drop door. Don't throw wet or damp rubbish into cinder ladles, as it may cause an explosion, and in turning a hose on a leaking cinder or iron ladle stand as far away as possible, as you may be scalded by steam or burned by an explosion, or shot if the water hits molten iron. Avoid walking on ash piles; they may be hot underneath and burn your feet if you break through. Keep your feet out of flue dust when cleaning it up. In loading or unloading cars see that the gang planks or runways are in good condition and are properly placed and secured.

Be careful when handling heavy material or using tools, as most accidents about blastfurnace plants are caused in such work. The cleaner you keep the yard the better and more safely everyone can do his work. Don't let piles of rubbish accumulate, or pieces of lumber, brickbats, scrap, and other material lay around, or leave tools about; someone may stumble over them. Fill up small holes and depressions and report promptly any steam or hot water puddles caused by leaky lines.

Always wear goggles or a mask when working about the troughs while iron is being poured; be cautious when the moulds are cold or if they have ice, snow, or water in them, and, especially when cinder is coming over, keep away as much as possible. When it is necessary to work under the strands to knock out the "stickers" keep from directly under the strand as much as possible, both the one you are working on and the adjoining strands. Men tending the lime vats and sprays should watch for stickers when it is necessary to go under the strands to adjust the sprays or to feed lime, while the machine is running. Aim to do such work between casts and shut off the steam when working about the sprays or vats. Before pouring examine the top of the ladle to see that there is no solid crust of cinder or iron frozen over the hot metal. Such crusts should be broken with a warm, dry bar, as otherwise the metal will splash badly when it breaks through the crust. Never operate the motors, clutches, or hoists for pouring ladles or running the strands unless it is your job, or unless you are told to do so by the foreman. Keep away from around the sprocket wheels. Remove the scrap and clean the rails between pouring ladles or casts. Don't try to save a few seconds by stepping on or across moulds in motion or containing hot metal; use the walks or go round if necessary. Be sure that the bars you use to bar scrap out of the troughs with are dry and warm, and avoid using short poling sticks. Before releasing the ladle after pouring replace all safety dogs or legs in position.

When you are working about the rear of the machine, wear goggles to protect the eyes from flying chips of iron or lime dust. Use care in loading cars to prevent side loading, overloading, and loading directly upon drop doors, and see that no pigs are left on the end frames where they may fall off.

When working on the pig machine strands, or changing moulds, see that motor switches are locked open, tagged with a danger sign, or that the clutch is fastened open. Avoid touching electric lines, motors, or light sockets, for where there is so much steam and metal floors as about pig machines, you may get a severe electric shock or burn. Keep sledges, cutters, and other tools in good condition, be careful in using them, and watch your hands and feet when handling moulds or pigs. Report cuts, burns, and bruises promptly.

Don't leave large pieces of scrap on the ladle spouts, they may cause accidents in shifting or pouring, and in removing them use a long bar and keep away from in front of the ladle; work from the side. Before trying to remove a bottom skull clear away all overhanging rim or side skulls and knock out any loose bricks. The bottom skull will then come out more easily and safely. Before removing a skull or cleaning a ladle be sure the ladle is securely blocked or propped. When trying to lift a rim skull out of a ladle with the crane don't stand on the rim of the ladle, the hook may slip and strike you or cause you to fall. Watch all ladles for iron frozen on the rim or spouts, skulls, and "hot spots" or signs of failure on the lining whereby hot metal might break through. A thin place in the lining is usually shown by the ladle shell becoming rusty red. Before using a ladle be sure it is dry.

LOCOMOTIVE FUEL TESTS.

ONE of the largest of the Mikado type of freight locomotives is being mounted on the locomotive testing laboratory of the Engineering Experiment Station, University of Illinois, for an extended series of tests. The Railway Engineering Experiment Station has entered into a co-operative arrangement with the International Railway Fuel Association and the United States Bureau of Mines to conduct tests with various sizes and grades of coal used for fuel. The Baltimore and Ohio railroad has loaned one of its newest freight locomotives for the purpose. This huge locomotive weighs, with its tender, a total of 464,000lbs. The testing laboratory is designed to permit the locomotive to be operated at any desired speed and at any power output under the same conditions as prevail in practice, while its performance is recorded by means of automatic equipment for measuring tractive effort, water consumption, fuel consumption, smoke production, and other factors which will enter into the investigations. The Baltimore and Ohio Mikado type of freight locomotive has eight driving wheels, each carrying a load of 28,000lbs., two pony truck wheels and two trailer truck wheels. It carries a steam pressure of 190lbs. per square inch, has a firebox 7ft. wide and 10ft. long, is 85ft. long, and delivers a pull or tractive effort of 54,500lbs. at its drawbar. Samples of coal to be used will be taken from Illinois mines and will be graded according to present commercial sizes ranging from the so-called slack and run-of-mine up to the commonly used "3 by 6 lump." Later, it is contemplated, tests will be made with a coal ground to an impalpable powder or flour, which will be injected into the firebox by means of a specially designed blower. Tests will be made with both hand firing and automatic stoker firing. It is the expectation that these tests will establish information which will enable a railway to determine how much it can afford to pay for the different grades and sizes of coal, and which grades and sizes will produce the best results under given operating conditions. The ultimate purpose of tests of this character which the University of Illinois is carrying on in many lines of activity is to provide the basis for the fuller and more economical utilisation of public resources. In these locomotive tests it is thought that the incidental benefits which may come to the public in the possible decrease of the smoke nuisance may alone justify the extensive work involved. The tests will be conducted under the direction of E. C. Schmidt, head of the Department of Railway Engineering, and will be in the immediate charge of J. M. Snodgrass, Assistant Professor of Railway Mechanical Engineering, and O. S. Beyer, First Assistant in the Engineering Experiment Station.

The Scarcity of Platinum.—The steadily increasing price of platinum is, says the "Financial Times," attracting attention to the Ronda lode in the district between Malaga and Gibraltar, to which public notice was directed at the beginning of the present year. It is understood that the Spanish Government has assumed the task of prospecting the Ronda lode. As is generally known, the Ural platinum mines, which are the richest known platinum mines in the world, are gradually showing signs of exhaustion, the output for 1915 having been less by half than that for 1914.

PUMPS FOR CONDENSERS.

THE accompanying illustrations show a design of pumps, the invention of Messrs. Hick, Hargreaves, & Co., Ltd., Soho Ironworks, Bolton, and Mr. James Gunn, of the type in which the barrel or water cylinder is submerged by a body of water contained in an encasing outer chamber, and is particularly applicable for use in connection with condensers and similar apparatus where it is desirable to operate upon a column of water that is liable to be hot and in which there may be vapours of such a character as to make the flow of the water sluggish or difficult when an ordinary suction or reciprocating pump is employed for the withdrawal and delivery of the water of condensation from the condenser.

Fig. 1 is a sectional elevation in diagrammatic form showing the arrangement of the submerged pump, and Fig. 2 is an elevation showing the pump when arranged in connection with the main condenser and the primary air and vapour ejector. The barrel D is in the form of a submerged cylinder, and is surrounded by an annular space A, into which water may flow to form, as it were, a delivery reservoir from which the piston or pump plunger C may draw in its up and downward stroke. In connection with the pump is arranged a settling chamber or collecting tank O into which the water from the condenser may fall direct or through a water cooler, and to this settling or collecting tank is arranged an ordinary pipe connection N for feeding and serving as the main suction pipe for the pump reservoir A. The collecting tank is fitted with a float P for controlling the supply of steam or the movement of the belt or switch for actuating the piston or crank of the reciprocating pump, so that the speed may be regulated by the movement of the float to suit the quantity of condensed steam water coming from the condenser, thereby maintaining a constant and predetermined water level in the collecting tank. This water level is arranged so that the pump may be supplied by a flow of water from the tank to the pump to an extent that will ensure the complete filling of the pump with water. The capacity of the pump is such that the speed of the plunger is slow in order that the water flowing into the pump under a very low or minimum head will completely fill the space in the chamber due to the displacement of the water plunger. When the head of the water flowing into the pump is insufficient to fill the space behind the moving piston and in order to ensure that this filling shall occur the pump barrel is surrounded by a chamber A which serves as an auxiliary feeder or reservoir, and is of such capacity that it is, while always full of water, in excess of the capacity of the pump chamber D, and is provided with valves F, B and communicating ports for permitting the water to be drawn therefrom at any predetermined part of the stroke. This chamber A is placed in direct communication with the vacuum space of the condenser by means of a pipe K, or with a pipe or branch connecting therewith (see Fig. 2), or with the suction pipe of the air ejector, thus ensuring the same pressure within the chamber as would be due to the head maintained by the automatic controlling device, the pipe K acting at the same time as a vent pipe.

About the pump barrel is provided a chamber M which is fed from the annular reservoir or supplementary suction chamber into which the main discharge pipe N from the automatic apparatus delivers, and within this chamber are the suction valves F B and openings L for the purpose of permitting an auxiliary feed into the pump barrel D to be secured when the plunger or piston has passed the openings L within the pump barrel that give communication to the chamber and thus enable the valves therein to be lifted by the flow of water, and the piston movement to be completely followed up for the entire length of its stroke. The barrel is formed with an upper stuffing box and gland which is arranged within the passage into which the water is delivered through the valves G and J from the pump barrel, so that the pump rod gland in connection with the pump barrel is completely covered with water and the leakage of air into the barrel thus obviated, the barrel and its valves E, F, G, R, B, J, being always under water and connection with the atmosphere thereby prevented. The valves for supplying the water to the lower part of the pump chamber are made to open directly from the intermediate or auxiliary suction reservoir or from the supply pipe from the automatic controlling apparatus for the inlet of the water, and to open also for the delivery of the water into a column or passage which leads to the upper common branch connection above the piston or plunger rod, and to which common branch the delivery pipe is connected for taking the water to any desired position. The upper suction valve R to the pump is made to open from the supply pipe N from the automatic controlling apparatus, and to be fed also by the auxiliary chamber A, while the upper delivery valve J opens directly into the common outlet branch chamber above the plunger rod. A connection H may be provided from the water space above the pump barrel to the controlling tank O in order to supply water under pressure to the external glands on the balance weight shaft of the float control tank for sealing purposes.

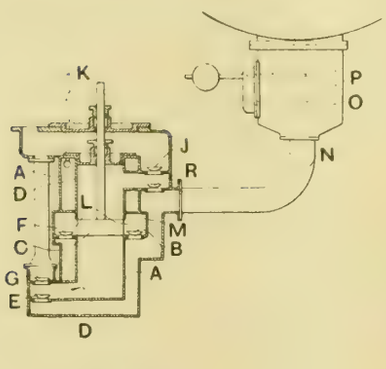


FIG. 1.

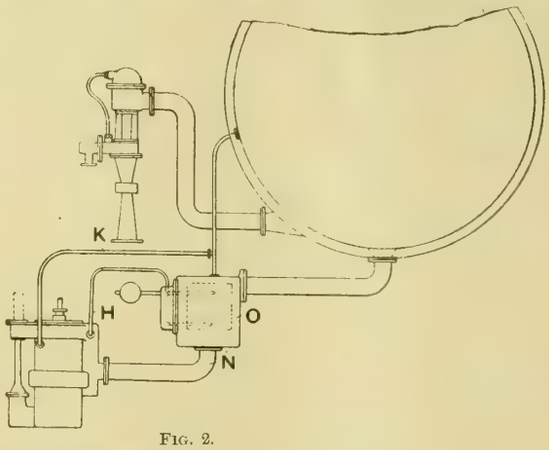


FIG. 2.

PUMPS FOR CONDENSERS.

CAN FOUNDRY SAND BE RECOVERED ECONOMICALLY? *

BY H. B. SWAN.

THE subject of waste foundry sand and the problem of its reclamation is not a new one to foundrymen, but it seems necessary to emphasize the ever-growing importance and need of systematic research to determine the possibility of reclaiming in a practical way the vast volumes of used moulding and core sands, especially the latter, which are daily being thrown away as waste material.

For the purpose of determining the status of the waste sand problem throughout the foundry industry, and more as a "feeler" than for any scientific record, the following set of 10 questions was sent out to a number of large foundries: (1) How much sand do you use (in tons) per day? (2) How much new core sand do you use per day? (3) Is your foundry practice green sand or dry sand moulding? (4) Do you use oil or other materials for core binders? (5) How much refuse sand do you dispose of daily (tonnage)? (6) How do you dispose of it? (That is, do you load it on cars on your siding or haul it away in wagons? Any details will be of additional value.) (7) How much do you know or estimate it costs you per ton to dispose of it? (8) Do you make use of any of your old core or moulding sand? If so, what percentage? (9) How much could you afford to pay for treating and using the whole or a portion of your old sand as against the cost of new sand? (10) Any information which you may add, bearing upon the above questions, will be appreciated and used, without mentioning names, in the investigation of a method to make use of the foundry refuse sand, and open to members of the American Foundrymen's Association through its transactions.

The answers to questions Nos. 1 and 2 of course varied

* Paper read at the annual meeting of the American Foundrymen's Association, Cleveland, September, 1916.

with the size of the foundry and the character of the work. To question No. 3, green sand moulding is by far in excess of dry sand work, except in the steel foundries. In reply to question No. 4, oil, flour, and pitch seem to be in almost universal use, all of which, after baking and resisting the action of the metal, leaves carbonaceous residues. In comparing the answers to question No. 5 with Nos. 1 and 2, it was found that in almost every case the amount of sand disposed of equals the amount of new core sand used, plus varying percentages of the moulding sand used. Thus it would seem that in most foundries where dry sand cores are used, no effort is made to re-use the burnt core sand, but that it all is disposed of as waste material. There are some exceptions to this, however, in special classes of work, such as car wheels, where as high as 50 per cent. of the sand as removed from the cleaning-room floor is used in the new core mixtures. In several cases the old moulding sand is treated for re-use.

Referring again to question No. 6, it was found that with one or two exceptions the burnt sand was either loaded in freight cars or hauled away in wagons to some dumping ground. While it is doubtless true that sand is the cheapest material which enters into the cost of the manufacture of castings, we find the cost of handling and disposing of it adds to its original cost as much as 100 per cent. This factor depends largely upon whether the sand is handled by mechanical means or hand labour; upon the situation of the foundry relative to dumping grounds, the latter condition in some cases of foundries located in large cities being a serious one; and also upon railroad facilities.

As exceptions to the rule we find one foundry disposes of some of its waste sand as a filler for a fertiliser; another writes that they have used some of their refuse sand for concrete mixtures. A portion of their experience is of interest: "We have used our burnt sand for putting in foundations for machinery, and we find that it serves the purpose very nicely, and in other places this burnt sand has been used in making cement floors, and these floors gave good service. We even used this burnt sand and burnt core sand in making concrete walls for a building, and the only bad effect that could be seen was that the flour in the cores made the walls flake. This flaking continued for a period of at least one or two years after the structure was completed, and was very noticeable, especially after a continued wet spell. The flour which was mixed in this burnt sand was evidently not thoroughly saturated with moisture when the concrete was poured, and upon long exposure to damp weather, it swelled sufficiently to flake off patches of concrete. In some cases only small parts the size of a dime, and in other cases larger patches the size of two hands, came off."

The answers to question No. 8 verify what has been said above to the effect that many made no attempt to re-use either the burnt core or moulding sand; a few treat a portion of the burnt moulding sand for re-use; and with one or two exceptions the used core sand is entirely discarded. In answer to question No. 9, many replies give no estimate; some state from 30 to 80 per cent. of the original cost of the sand.

The personal experience of the writer has been, in attempting to use burnt sand in new core sand mixtures that the cores are weak, soft, require an excessive amount of binder, and do not resist the action of the metal well. Even after burnt sand has been washed and cleaned, if examined under the microscope it will be found that the individual grains are coated with a black carbonaceous residue. These absorb an excessive amount of binder, and where seacoal has been used either in facing sand or in the core-sand mixture, this has been coked, and it is impossible from our experience to wash it all out. It must also be borne in mind that nearly all foundry sands contain a small amount of alkalis which are inimical to oil binders.

The Society of Engineers.—A meeting will be held at 3 p.m. on Monday, December 11th, in the Apartments of the Geological Society, Burlington House, Piccadilly, W., when the following papers will be read: (1) "The Sources of the Minerals Required by the Iron and Steel Industries of the United Kingdom," by Prof. William G. Fearnsides, M.A., Sorby Professor of Geology, University of Sheffield; and (2) "The Mineral Resources of the British Empire as regards the Production of Non-ferrous Industrial Metals," by Prof. C. Gilbert Cullis, D.Sc., Assistant Professor of Geology, Royal College of Science, London.

PULVERISED-FUEL INSTALLATION FOR STEAM RAISING.

In the course of the discussion on the paper on "The Use of Powdered Coal as a Fuel" presented before the American Society of Mechanical Engineers, and reproduced on another page of this issue, Mr. H. G. Barnhurst furnished particulars of an installation for preparing and burning pulverised low-grade coals, including lignite, under boilers which is now being completed at the shops of the Missouri, Kansas, and Texas Railway Company, and which is the first and largest commercial installation of its kind in existence. The boilers in the plant (O'Brien, 250 h.p.) are arranged in one continuous row of three and one batteries, respectively, there being a space between the settings of each pair of two boilers of 4ft. 8in., and a space between the two batteries of 28ft. 4in. for feed pumps, auxiliaries, &c. At the far end of the battery of two boilers space is allowed for four more boilers, which will then make 12 in all. Eight boilers are now installed, and equipment is supplied for 10.

The boilers are to carry 150lbs. steam pressure, the feed water being delivered to the boilers at 208° Fah. Based on a boiler efficiency of 70 per cent., operating full capacity for 10 hours, and half capacity for 14 hours, about 158,000lbs. of coal will be consumed in 24 hours, or 79 net tons for the 10 boilers. When the two additional boilers are added, a total of 94 tons per day of 24 hours will be required. Two 42in. Fuller mills operating 12 hours per day will readily produce 96 tons to 100 tons of pulverised coal, which will be more than ample for this plant.

The Pulverising Plant.—The coal which is used in this plant is dumped directly from the cars into a concrete and steel hopper beneath the track which runs parallel and adjacent to the power house and coal plant. As a large percentage of it will be mine run, a 20in. by 24in. spike-toothed roll crusher is placed directly beneath the hopper discharge to break down the large lumps it contains. This crusher is driven by a bell-connected motor, 15in. centres, placed in the inclined tunnel leading from the track hopper to the coal plant, a building 43ft. by 54ft.

A 20in. belt conveyor, with its receiving end directly beneath the discharge from the toothed roll crusher, conveys the coal through an inclined tunnel to the coal plant, the near wall of which is 25ft. from the centre of the track hopper, this distance being determined by the difference in height of the receiving and delivery ends of the belt conveyor. At the delivery end of the belt conveyor a 24in. by 22in. magnetic separator pulley is placed to hold and remove any tramp iron that will be brought along with the coal, and the coal is then discharged into a pair of 24in. by 18in. corrugated rolls driven along with the belt conveyor by a motor of the belted type. From the corrugated rolls the crushed coal is carried up in an elevator, discharged into a screw conveyor and carried along to a bin over the back end of the drier. This bin has a capacity of 40 tons, which allows a storage ahead of the drier and mills of five hours. The elevator and screw conveyor are both run by one motor.

The Conveying Machinery.—From the bottom of the bin a screw conveyor feeds the coal to the back end of a 4½ft. by 30ft. indirect-fired rotary drier, both being run by one motor. The coal passes through the drier and is discharged to an elevator at the front end. A screw conveyor located in the floor also carries the tailings from the settling chamber beneath the drier stack to the elevator. The dried coal and tailings are elevated, discharged into a screw conveyor, and carried to the bin over the pulveriser. This bin is placed in front of and high enough above the mills to enable all the coal to be fed to them by gravity, and has a capacity of 45 tons. The elevators and conveyors over the bins are operated by one motor. There are two pulverisers.

The pulverised coal is delivered by spouts from the pulveriser mills directly to an elevator and raised to a screw conveyor which carries the coal to the boiler house. The conveyor and elevator are both operated by one motor. This conveyor is carried over a bridge 30ft. long between the coal plant and boiler house, and continues on through the entire length of the power house over the bins in front of the boilers, thus making a single straight-delivery unit from coal plant to bins about 216ft. in length.

One bin is placed in front of each pair of boilers. These bins are rectangular in shape but have divided hopper

bottoms, thus enabling the coal to be fed by separate feeders to each boiler. Each half of the bin with its hopper bottom will hold 10 tons of pulverised coal, which will provide storage in front of each boiler for a run of 20 hours at full capacity. This allows ample capacity, so that any delay in the coal mill proper will not interfere with the continuous operation of the boilers for a period of over 24 hours if the boilers are run under ordinary operating conditions. Each bin is filled through three separate gates with spouts in the bottom of the conveyor, so that the supply to any bin can be controlled as desired.

Air Blast for Feeding the Coal.—Underneath and between the sides of the inverted "V" formed by the two hoppers of the bin is placed a direct-connected motor driven fan with a down-blast discharge which is divided into two 7in. blast pipes. These two pipes diverging at an angle of 60° with each other coming down in a plane parallel to the front of the boilers, about 8ft. from the front wall of the firebox or combustion chamber, make an easy sweeping bend and discharge into the burner nozzle located in front of each boiler 3ft. from the floor. The fan supplies the air needed in feeding the coal (4,200 cub. ft. per minute) at 3 oz. static pressure to a burning nozzle in front of each boiler.

At the bottom of each of the two hoppers of each bin is a 4in. screw feeder enclosed in a circular cast-iron casing. Above each feeder, between the hopper and the screw proper, is a slide, so that if for any reason the feeder should become jammed or broken it could be readily removed without first drawing the coal from the bin. Each feeder is chain and sprocket driven by a 2 h.p. variable-speed back-geared motor, the controlling rheostat of which is located in a convenient position in front of the boilers.

The Burners.—Each feeder discharges into a 3in. pipe, 8ft. long, which drops the coal straight down and into a funnel-shaped opening in the top of the burner nozzle. This burner is ideal for the purpose, as it is both simple and highly efficient. It consists of an outside 14in. cylindrical pipe, one end of which projects into the furnace; into the other end the 7in. blast pipe is inserted and extends inwardly from 12in. to 18in. A metal cone is fitted over the blast pipe so that it can be moved back and forth any desired distance, thus forming a valve to regulate the amount of air that is induced in the burner or to close the opening entirely if desired. Directly over the inserted end of the blast pipe a small funnel-shaped cone is placed in the outside pipe, into which the cone is fed and drawn in by the suction formed by the blast. The funnel opening into which the coal is fed is directly over the discharge end or nozzle of the blast pipe, so that the coal will be drawn in and thoroughly mixed with the blast and induced air before reaching the combustion chamber of the furnace.

A large quantity of air can be induced in this burner, which, together with that blown in by the fan, will supply all the air required for combustion. The blast pipe is provided with a 2in. screw-capped opening just back of the sliding cone, so that the pressure and velocity of the air can be determined when desired. The outside burner pipe is also provided with two similar openings, one between the coal opening and the open end, and the other about 1ft. from the furnace wall.

At normal rating on a basis of 70 per cent. efficiency and with feed water at 208° Fah., these boilers will each consume 958lbs. of coal per hour or 16lbs. per minute, and will therefore require about 3,200 cub. ft. of air per minute for combustion. Half of the capacity of the fan (or 2,100 cub. ft.) will be supplied through the 7in. blast pipe to each boiler, the remainder being induced by the action of the blast in the intake end of the burner.

The Furnaces or Combustion Chambers.—The furnace or combustion chamber of these boilers is well adapted for firing with pulverised coal, in that it has 583 cub. ft. of volume or, at normal rating, 36·4 cub. ft. per pound of coal fired per minute. The bridge wall is located 7ft. from the front wall of the setting and from the end of the burner. The baffle wall, which in the standard O'Brien boiler is carried on the bottom row of tubes, has in this case been replaced over the combustion chamber with bricks, with a U-shaped opening in one side to fit the tube so that when inserted the two together will completely surround the bottom of any tube, and thus serve to protect the tubes from the direct action of the flame and likewise offer a combustion chamber whose top, bottom, and sides present to the entering coal dust a surface entirely lined with refractory firebrick, the top or roof being protected by the tubes. From the base of the arch wall, on a level with the floor of the boiler room, the bottom of the combustion chamber slopes downward toward the front at an angle of 45° till it reaches a point directly under the front setting, where a shelf 2ft. wide projects straight out to a door in the ash tunnel through which steel cars are operated and into which the ash and slag which is precipitated on this shelf is raked. The bottoms of these ash doors are located 7ft. below the floor of the boiler room, and the tops of the cars just come to within 3in of this level, so that all that is necessary is to move the car in front of the ash door. The sides of this sub-combustion chamber extend vertically downward from the floor level for a distance of 3ft. 6in. and then converge toward the centre at an angle of 53° with the vertical until they meet the above mentioned bottom shelf 2ft. apart, so that the bottom of the furnace or combustion chamber forms a firebrick-lined hopper with a bottom 2ft. square. The remaining front wall of the furnace is, of course, extended straight down to 3ft. 6in. below the floor level and cut under in a sloping arch parallel to the rear side so that it will form a sloping roof to the top of the ash door.

The area between the top of the bridge wall and the bottom row of brick-protected tubes is 19 sq. ft., and with a temperature in the furnace of 2,800° the velocity of the gases over the bridge wall at normal rating will be about 16ft. per second. With such a low velocity it can be readily seen that the greater part of the process of combustion should be completed before the gases pass over the wall, and also that a large percentage of the ash or slag will be deposited in the hopper bottom. There is also a settling chamber back of the bridge wall, and any ash that settles in this chamber can be raked out of a door at the side.

Appendix.—Since this discussion was submitted, the plant has been put into successful operation, and developments have made it advisable to alter the furnace design somewhat. With Kansas coal, containing approximately 22 per cent. ash, the horizontal baffles allowed too much ash accumulation, so a Dutch oven approximating a 6ft. cube was built in front of each of two boilers and vertical baffles were inserted replacing the former horizontal ones. With these changes highly gratifying results are being obtained. No slag is formed and the ash is readily blown off the floor of the rear chamber with an air hose once a week. No part of the refractory lining is subjected to an excessive temperature even at considerable overload. The Missouri, Kansas, and Texas R. R. officials are very enthusiastic concerning the operation and economies being obtained both with the aforementioned 22 per cent. ash coal and also with lignite, and the Dutch ovens and vertical baffles are being installed as promptly as possible for the other boilers. The operation is quite flexible and by the most simple adjustments almost any furnace conditions can be realised, the capacity being varied at will.

THE KEADBY LIFTING BRIDGE.*

BY JAMES BENJAMIN BALL, M.INST.C.E.

THE Great Central Railway Company have recently completed an important bridge over the River Trent at Keadby, about 14 miles north of Gainsborough, of which the chief feature is a lifting span, built on the Scherzer principle, which claims the distinction of being the heaviest lifting bridge yet constructed in Europe. The new bridge replaces the old swing-bridge at Keadby which has carried the railway for over 60 years, and in addition carries a public highway in satisfaction of a long-felt want. The new structure consists of a combined railway and roadway bridge of five spans of the following dimensions: Two fixed river spans of 135ft. each; a lifting span of 160ft., giving a clear waterway of 150ft.; a track span of 40ft. on which the lifting span rolls; and an approach span of 70ft. on the east bank of the river. The bridge has a width of 53ft. 6in. between the centres of the outside girders, of which 29ft. 3in. is occupied by the railway and 24ft. 3in. by the roadway, each span consisting of three main girders, the centre one dividing the roadway from the railway.

The river piers, of which there are four, are faced with

* Abstract of paper read before the Institution of Civil Engineers, November 21st, 1916.

granite and founded on rectangular steel caissons filled with concrete and sunk under compressed air to a depth of 50ft. below low water. The largest of these caissons has an overall length of 94ft., a width over cutting edges of 20ft., and a permanent height of 32ft. Difficulty was encountered in the early stages of sinking through one of the caissons tilting forward and moving bodily towards the river, which threatened serious results, but steps were taken which proved effective in arresting any further movement, and the caisson was finally righted during sinking in the new position it had taken up.

The two fixed river spans are similar in design, the main girders being of the ordinary N type, 17ft. in depth, divided into 10 panels, and counterbraced in the two centre bays. The cross girders are suspended from the vertical posts below the bottom booms and spaced 13ft. 6in. apart; between them ordinary roadway and railway stringers carry the deck plating. The top booms are connected by portal bracings at each vertical post, intersected by diagonal wind-bracing, and provision for longitudinal expansion is made at the junction of the spans by means of cast-steel bearings mounted on groups of rollers. The total weight of steelwork in each of these spans is 540 tons.

The three main girders of the track span form a path on which the lifting span rolls, and together have to sustain the weight of the lifting span, which is nearly 3,000 tons. These girders, which are of very heavy construction, have an effective length of 40ft. and a depth of 10ft., and carry on their upper flanges cast-steel plates, 3½in. thick, on which the teeth are formed, engaging with corresponding slots in the segmental girders of the lifting span.

Considerable attention was given in the design of the bridge to the question of the contact pressures obtaining between the segmental girders and the track plates upon which they roll, and for the purpose of determining the probable arc of contact, careful experiments were made, particulars of which are recorded in the paper.

The lifting span consists of three main trusses spaced at the same distances from one another as the main girders in the fixed spans, and taper from a depth of 36ft. at the rear end to 18ft. at the fore end. Cross girders, spaced 19ft. 8½in. apart, with longitudinal stringers between them, carry the deck plating of the road and railway, respectively, whilst the upper booms of the trusses are connected together by substantial overhead portal bracing on each of the vertical posts, which, together with the wind-bracing above and the floor members below, tie the trusses together, thus securing rigidity in the span as a whole. The lifting span is counterweighted at the rear end in order to secure balance at all angles of lift, the counterweight consisting of a rectangular steel shell extending across the full width of the bridge, and heavily braced internally by lattice frames and strengthening girders. Its internal capacity is 24,780 cub. ft., and it contains 1,800 tons of concrete.

Between the rear ends of the trusses and the under side of the counterweight, compound plate-web segmental girders, having a radius of 28ft., are provided. These girders have a central depth of 10ft., and on their bottom flanges are bolted segmental plates of forged steel 3½in. thick, provided with slots to engage with the teeth of the track plates on which they roll. On either side of the lifting span heavy frames are built up alongside the track girders and anchored down to the supporting piers of the bridge. These frames at their upper extremity carry horizontal girders, to which are bolted the main operating racks. Between these frames sufficient clearance allows the span to move freely as the bridge is raised or lowered.

The position of the racks coincides with the centre of the rolling circle of which the segmental girders form part, and the rotation of the pinions attached to the gudgeon pins of the moving leaf as they travel horizontally along the racks, rolls the leaf backwards or forwards, so opening or closing the bridge. A horizontal platform at the level of the fixed racks is constructed on the leaf itself, and on this platform the lifting machinery is accommodated.

The total weight of steelwork in the lifting span is 987 tons, exclusive of the machinery and gearing, and the total weight of the moving span, together with its counterweight, is approximately 2,920 tons. The lifting span is worked electrically by means of two 115 h.p. direct-current motors, carried on the leaf itself, the power being transmitted through trains of gearing to the main pinions on each side. The angle of maximum elevation of the bridge when fully open is 81°51, and the time taken to open or close it by electrical power is less than 2 minutes.

Owing to the absence of power in the neighbourhood, a special plant for the generation of current had to be put down, consisting of two direct-coupled petrol engines driving two 50 kw. continuous-current machines, the current being delivered at the switchboards at 220 volts. A large storage battery is provided, capable of supplying the motors with current for about 30 operations of the bridge before recharging is necessary.

Two sets of electric brakes are provided, and at the fore end of the span two heavy forged steel bolts, worked electrically from the control cabin, engage with castings anchored down to the pier, so locking the bridge when in the "down" position. To prevent the too rapid descent of the leaf as it comes down on to the bearings, a pneumatic buffer is provided at the front of the span, whilst at the rear end bumping blocks are provided on to which the counterweight comes down when the leaf attains its maximum elevation. Adjacent to these blocks, hydro-pneumatic buffers are fixed, the rams of which, coming into contact with the counterweight, bring the bridge gradually to rest as it reaches its final position. In order to meet the requirements of the Navigation Authorities, the lifting span was erected in a vertical position, 10 months being occupied in this work.

Electrically-operated gates are provided for the protection of roadway traffic, which are interlocked with the railway signals, which latter, it may be observed, are what are known as three-position signals, and are the first to be installed as a complete scheme in this country. Work was commenced in August, 1912, and following the Board of Trade tests, which were carried out in March and April, 1916, the bridge was opened to traffic on May 21st.

HOW OLD METAL IS RECLAIMED IN A LARGE PLANT.*

BY J. M. BATEMAN.

IN large manufacturing plants, where vast quantities of raw materials are consumed, the task of economically disposing of waste incident to the manufacturing operations becomes a serious problem. At the Hawthorne works of the Western Electric Company, Chicago, where materials approximating £300,000 in value are used each month, old metal is being reclaimed by means of a system that is said to have proved very satisfactory. The following figures, which represent approximate monthly averages of the large items of junk disposed of to outside concerns, will possibly give a clearer idea of the amount of material involved: Brass, 100 tons; copper, 180 tons, including 125 tons from the cable, rubber, and insulating shops; German silver, 17½ tons; iron and steel, 89 tons; solder skimmings, 4 tons, and lead, 833 tons.

A vast number of the parts used in the manufacture of telephone apparatus are punched from sheet metal, brass, iron, or German silver. This operation, of course, leaves as waste a certain portion of the original sheet or strip. All brass, copper, German silver, &c., is kept separate by material in the operating departments, and sent to the by-products department, where it is baled in a Minich baling press. This electrically operated press compresses the waste material into a bale approximately 2ft. wide, 2½ft. thick, and 3ft. long, which, when completed, weighs approximately 1,100lbs., depending to a large extent upon the shape and size of the material used. A Logemann hydraulic bundling press, which has recently been installed, is especially adapted to work of this kind, for not only is it easy to operate, but junk baled in a press of this type commands a comparatively high price, and the bales are compact and readily handled, weighing only about one-tenth as much as those formed in the Minich machine. The baling machine handles the larger pieces of scrap material, while the chips, turnings, and sweepings from

* Paper read before the American Institute of Metals, September, 1916.

the machine departments are taken care of in a different manner.

The apparatus used for separating the dust and dirt from the small chips and metal shavings is very simple in construction, consisting simply of a sifter which is oscillated by a small motor. Thus, the dust and dirt are separated from the usable chips and shavings. The magnetic separator used in separating the iron from the brass in the sweepings comprises a revolving drum having an annealed iron face, driven by a small motor. Within the drum is a series of powerful electro-magnets, which extend in the form of an arc approximately from the bottom of a hopper to a point directly below the shaft on which the drum revolves. The chips and shavings shovelled into the hopper travel down the chute, which is at all points parallel to the periphery of the revolving drum. The brass shavings travel down this chute into a box, while the iron chips which may have been mixed with them are attracted by the magnets to the soft iron face of the drum, where they are held until they reach a point where they are released by the magnets. Both kinds of chips are then put up in sacks for convenient handling.

The scrap cable is first placed in gas-heated, brick-encased ovens, where it is heated until the lead sheath has been melted and the paper insulation has been burned from the wire. The molten lead is run off into a refining furnace, where it is automatically separated from the paper ash and other impurities which it contained when taken from the melting furnace. Before the present apparatus was installed the molten lead was made into pigs direct from the melting furnace, which necessitated an additional handling, as it had to be refined before being fit for sale. After the refining operation is completed, the molten lead is drawn off into moulds. These moulds are mounted on a turntable, so that one man can manipulate the levers. One lever opens the gate and allows the metal to flow into the mould, while the other lever turns the table upon which the moulds are mounted. As the filled moulds pass around toward the left they travel under running water, which cools the lead, so that the moulds, which are pivoted, can be tipped and the pigs of lead extracted. While a portion of this lead mixture can be used in the press room, much of it contains too great a percentage of impurities to meet the severe requirements demanded in the manufacture of cable, and therefore it is sold to refining companies to be further purified. The copper wire remaining in the furnace after the lead has been run off is placed in the Logemann press and compressed into brick form before being sold.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Manufacture, centrifugally, of pipes, columns, and other hollow articles. Moir & Buchanan. 12928.
Pipe joints. Marks. 15574.
Gas producers. Nelson. 16088.
Furnaces fed with pulverulent fuel. Von Porat, and Motala Verkstads Nya Aktiebolag. 16298.
Universal joint or gear adapted to transmit rotary motion in the same axial line or at an angle. Hoskins. 16561.
Roller bearings. Michaud, Müller, & Heibel. 17095.
Apparatus for heating oil fuel. Abell. 17467.
Carriers for connection with aerial ropeways. Bullivants' Aerial Ropeways, Ltd., and Gray. 17596.
Manufacture of heat-insulating material. Cuthbertson. 17949.
Producers for water gas. Sefton-Jones. 18218.

1916.

Regenerative furnaces. Drakes, Ltd., and Drake, W. A. 7.
Cobalt chromium alloys. Haynes, E. 192.
Liquid-fuel supply arrangements of internal-combustion engines. Higginson, J., and Arundel, H. 200.
Holder for wire ropes or cables. Best, J. 467.
Parting or cutting-off machines. Clifton & Baird, Ltd., and Clifton, C. H. 562.
Discharge valves. Barclay, Curle, & Co., and Bell, J. 1217.
Crank chambers of internal-combustion engines. Craig, A. 2311.
Furnaces for calcining copper ores. Squire, J. G., 2424.
Piston-rod packing. Paxton, J. L. 2502.
Compression release mechanism for two-stroke-cycle air-cooled internal-combustion engines. Villiers Engineering Company, and Funck, G. 2707.
Internal-combustion engines. Riper, L. C. van. 2982.
Two-stroke internal-combustion engines. Knight, J. F., and Doudney, R. P. 3439.
Rotors and casings for rotary engines. Speese, J. 3609.
Devices for closing the slits of packing rings. Rasch, L. 4526.
Gear for giving motion to indicators and counters for reciprocating machinery. Mustart, J. W. S., and Mackenzie, M. 5719.
Lock nuts. Van der Valk's Certitudo Patentmoer, and Panthaleon, Baron van Eck. F. M. van. 6779.
Stuffing-boxes. Guttner, M. 7048.
Elastic-fluid engines. Machin, W. A., Mills, E., and Downes, A. 9854.
Steam boilers. Shenton, R. 10164.
Engines arranged in groups. Bugatti, E. 10831.

ELECTRICAL, 1915.

Electromagnetic power-transmission gearing. Zoelly. 14111.
Circuit connections of electron discharge apparatus. British Thomson-Houston Company. 15448.
Telegraph apparatus. Mellersh-Jackson. 15579.
Electrically-controlled clutches. Langdon-Davies, Soames, and Naamlooze Vennootschap. 15762.
Automatic protective gear for electrical systems. Rosebourne (formerly Rosenbaum) & Couse. 16053.
Lightning arresters. Marks. 16056.
Electric supply meters. Merriman & Speirs. 16058.
Dynamos of the commutator type. Walker. 16854.
Connection between electric incandescent lamps and holders. Fildes. 17060.
Electrically-driven vehicles. British Thomson-Houston Company. 17128.
Electric regulating systems. Campbell. 17166.
Reversible electric step-by-step ratchet mechanism. Parsons and Ball. 17570.

1916.

Electric lighting system or circuits. Wrigley, H. 358.
Electric discharge vacuum tubes. Dushman, S. 2328.
Miners' electric hand lamps. Railing, A. H., and Angold, A. E. 2552.
Electric furnace. Wrighton, W. J. 2584.
Combined electric lamp holders and switches. Donovan, W. 4752.
Electric heating apparatus. Erichsen, E. 7275.

METAL QUOTATIONS.

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,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled	1/4¾ per lb.
,, tubes (brazed)	1/7¾ ,,
,, ,, (solid drawn)	1/5¾ ,,
,, ,, wire	1/4¾ ,,
Copper, Standard	£145/–/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£32/5/– ,,
,, Foreign (soft)	£30/–/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
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Chemistry and Engineering.—At a recent meeting of the Society of Chemical Industry, Dr. Charles Carpenter, the president, said that the future of the chemical industry could be secured by the co-operation of the two professions. In the past there had been prejudice between the two professions, inasmuch as engineers had always kept their operations strictly secret from the chemists. The need for men with knowledge of both engineering and chemistry was becoming a national one. The engineer and the chemist should take each other into confidence. The engineer should be taught enough of chemistry to appreciate the chemist's point of view, and the chemist enough of engineering to appreciate the engineer's point of view.

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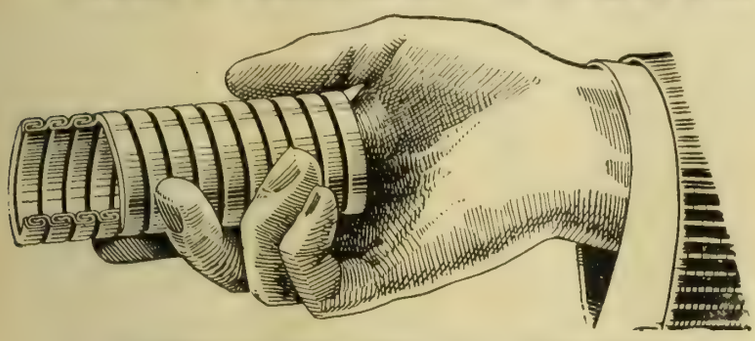

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British Contributions to Gas Engine Development.

A FEW years ago British engineers were taken rather severely to task by a section of college professors and other interested persons for their apathy and apparent lack of enterprise in the development of large gas engines, and their attitude was made the subject of comparisons between German and British engineers, disparaging to the latter. Dr. Dugald Clerk's paper on the development of the internal-combustion engine, read before the Royal Society of Arts, comes as a timely corrective to these distorted views, and places in clearer perspective the work of British inventors and engineers in the origin and development of this type of prime mover. We are too prone to self-criticism, and though this may sometimes be a virtue in times of peace, it is, as Dr. Clerk observes, as harmful in such periods as the present to underrate our own strength as it is to underrate the power of our enemies. There is no doubt much injustice has been done to British pioneers by the indefatigable propaganda of German science, and the bias it has produced in the minds of some of our prominent men, and his review should serve to dispel this delusion. As we purpose reproducing the paper in full, we need not enter fully into details here, though some of the salient facts are worth repeating, and we would commend its perusal to all readers who take an interest in the subject, on which Dr. Clerk is one of the highest authorities. His interest in gas engines commenced with experiments with the Otto and Langen motor in 1876, when the largest gas engine did not develop more than 3 b.h.p., and 40 years' subsequent association with its development, it will be admitted, enables him to speak with authority. This period has witnessed the growth of these primitive practical motors, the total power of which at the date mentioned in the United Kingdom did not exceed 2,000 b.h.p., until in 1907 the census of production showed that our factories alone had a total of

680,177 h.p. in operation, while agriculture employed 98,785 h.p. of gas, petrol, and oil engines, in addition to which there were in use in motor-cars not less than 750,000 h.p., generated by petrol engines, making altogether a total of over 1½ million horse-power. Similar figures for Germany showed for the same year a total of 531,000 h.p., or little more than one-third of the similar power in this country. The fact that Dr. Otto in 1876 produced the first commercially successful gas engine, and that his name is associated with the 4-stroke cycle, has obscured the credit due to earlier British inventors; compression before ignition, for instance, on which gas engine efficiency so largely depends, was proposed 38 years earlier by the Englishman Barnett in his patent No. 7615 of 1838, and in 1862 M. Alph. Beau de Rochas, a Frenchman, in a pamphlet discussing the conditions of economy in gas engines, outlined the 4-stroke cycle, now often described as the Otto. Prior to Barnett, and long before any German inventor appeared, several Englishmen had worked on the gas engine idea, and patents relating to it were taken out as early as 1791, though it was not until 1876 that commercial development may be said to have begun, and this, it should be remembered, was largely due, in its earliest stages, to Messrs. Crossley Bros. Dr. Clerk himself came on the scene the same year as Dr. Otto, and patented his engine in 1881. As the various types of engine are described in Dr. Clerk's paper, we need not discuss them here. Suffice it that the cycle was essentially the same in all, and that subsequent developments have been devoted mainly to diminishing the number of strokes per revolution, to increasing the power per cylinder, and other details to secure greater smoothness and efficiency, while on parallel lines engines have been developed using liquid instead of gaseous fuel. Alongside these developments a great deal of original work has been done by British workers regarding the thermodynamic problems of combustion. As regards large gas engines, higher fuel cost in Germany has undoubtedly played a large part in concentrating attention on it there, owing to the superior thermodynamic efficiency of the gas engine as compared with the steam engine, which still rules pre-eminent here. English engineers have all along looked rather askance at the big gas engines, although some firms have taken up their manufacture under German license, and experience and investigation alike tend to justify this view. Large gas engines are abnormally heavy, the weight increasing much more rapidly than the power, while the high temperature makes the problem of heat transmission to the cylinder wall so difficult as to place a practical barrier to size, notwithstanding the ingenuity in design that has been spent in trying to overcome it. Experience, in fact, goes to show that increased power beyond a certain limit of size must be sought rather in a multiple of cylinders than a single one. That there is still, however, ample room for development of the internal-combustion engine, and that the steam engine is still not the decrepit rival some would imagine, is clear from the fact that at the present time the total power developed in the country is nearly 11 million horse-power, and that of this only about 6·4 per cent. is produced by internal-combustion engines. In the United States the proportion is even smaller, only about 4·2 per cent. out of a total of 23¼ million horse-power being produced in this way.

Encouragement of Scientific Research.

As our readers will be aware the Government has decided to take more active steps in the promotion of scientific and industrial research. It may be regarded as one of the by-products of the war and the abandonment of that *laissez faire* policy which a few years ago was the traditional Government attitude, and in striking contrast to that pursued in Germany and the United States. It is announced that subject to the consent of Parliament a large sum of money is to be placed at the disposal of the new organisation for the conduct of research on a co-operative basis, instituted for national industries, and to promote this estimable object the Board of Inland Revenue has, it is officially stated, condescended, with the approval of the Chancellor of the Exchequer, to offer no objection to the allowance as a working expense for income-tax purposes of contributions made by traders to industrial associations formed for the purpose of scientific research. Having regard to the national character of such work it is to be trusted traders will be duly thankful for this small mercy. They must carefully note, however, that "such contributions must be out and out payments made from trade profits, and giving them no proprietary interest in the property of the association," and in order to enable the department to hold the new fund a Royal Charter has been granted to the Committee of the Privy Council to create a trust empowered to accept, hold, and dispose of money for the object in question, including sums voted by Parliament. It is added that a substantial gift has already been made to the trust by two members of the Institution of Mechanical Engineers for the conduct of a research in mechanical engineering to be approved by the department, and the hope is expressed that "this example will be followed by other members of the Institution." While engineers generally will be ready to pay a tribute to this act of anonymous generosity they will, we are sure, feel with us that its official acknowledgment bears rather too much the appearance of an intimation that "further contributions will be thankfully received," and that financial support for an obviously national work runs a risk of resting too much on private donations. Perhaps we are doing the powers that be an injustice in suggesting this. We hope it may prove to be so, but it is well to protest against any suspicion of this kind.

AUTOMATIC LUBRICATING APPARATUS.

THE accompanying sectional views show a design of mechanical lubricator of the kind in which a pump or pumps, operated from a moving part of the engine or machine, forces oil from a reservoir through pipes to the parts of the engine or machine to be lubricated, the invention of Mr. John Thomas, 60, Culmington Road, Ealing. The apparatus employs double-acting pumps and a positively actuated valve arranged to co-operate with a pair of pump plungers so as to alternately permit oil to be forced or delivered to the oil outlet pipe of the apparatus by the pumping stroke of one and the other of the pair of plungers. By the employment of a positively actuated valve the apparatus, it is claimed, is rendered less liable to failure and thus more efficient in working than apparatus in which automatic ball valves or spring controlled valves have been employed for controlling the admission of oil to the pump barrels or plungers.

Referring to the illustrations, Fig. 1 is a sectional elevation taken on the line 1, Fig. 2, longitudinally through one pair of double-acting pumps forming a unit. Fig. 2 is on the left-hand side a section taken through the line 2, Fig. 1, and on the right-hand side a section taken through the line 3, Fig. 1. As each pump unit is identical, the working of each double-acting pump of the unit is identical, so that the description of the action of one pump will be sufficient. Referring to Fig. 1, when the lower plunger A, moving to the left, reaches

the end of its pumping stroke, the other lower plunger B has reached the end of its suction stroke, in which position of the plunger B the port C is open to the oil-box D so that oil will flow through the port C and passage E in plunger B into the chamber or pump barrel F in the regulating screw G; the direction of travel of the plungers A and B is now reversed, by the continued motion of the cam H due to the action of the pawl J on the ratchet wheel K, and plungers A and B, moving to the right, become respectivly a suction plunger and a pumping plunger. As the plunger B moves inwardly in the barrel F the port C enters the inner end of the screw plug G and is thus cut off from communication with the oil-box D, and the oil already admitted to the barrel F is forced through the passage E of plunger B, and acting on the right-hand end of the cylindrical valve L forces this valve over towards the plunger A, thus closing the port M in the cylindrical part N which connects the

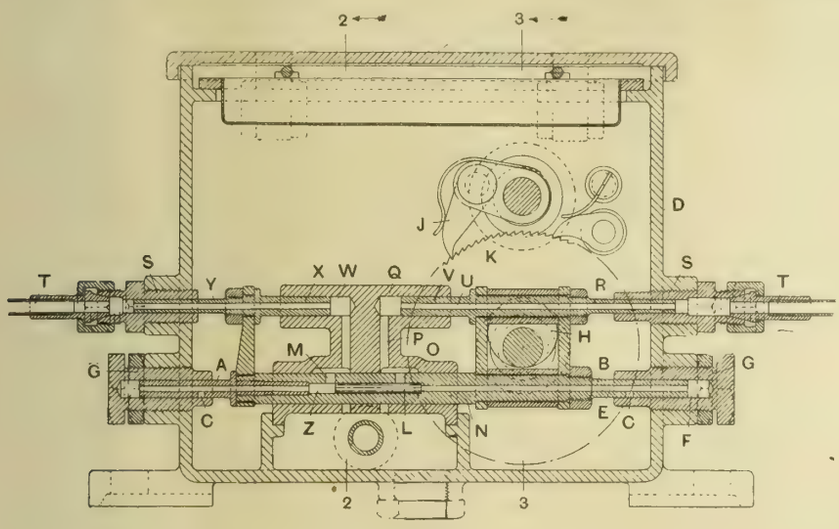


FIG. 1.

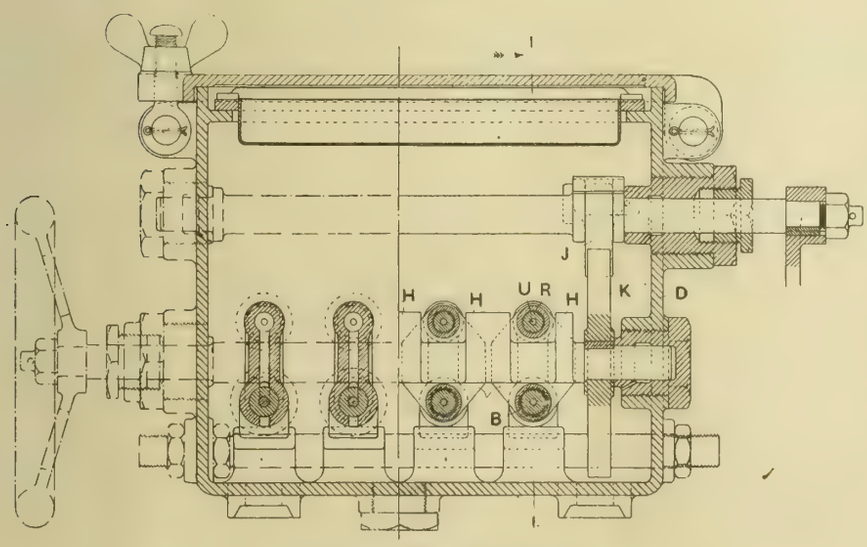


FIG. 2.
AUTOMATIC LUBRICATING APPARATUS.

plungers A and B and opening the port O in the part N whereupon the oil will, as the plunger B continues its pumping stroke, be forced up through the passage P into the pump barrel or chamber Q of the upper plunger R.

During the pumping stroke of the plunger B the outer or right-hand end of the plunger R, moving outwardly (towards the right) in the chamber in the screw plug S, is acting as a pumping plunger and forces oil out through the delivery pipe T, past the usual check valve to the usual pipe leading to the part to be lubricated, this action taking place owing to the fact that, in the working of the apparatus, the chamber Q, the passage U in plunger R, the chamber in the screw plug S, and the pipe T are completely filled with oil, these chambers and passages being kept filled with oil by the pumping strokes of plunger B.

As the cross-sectional pumping area of the lower plunger B and that of the enlarged diameter part V of the upper plunger R are identical, and as the travel of both these plungers is the same, it follows that the quantity of oil sent forward by the plunger B will fill the chamber or barrel Q as the larger diameter portion V of the plunger R moves outwardly in chamber Q, and further as the cross-sectional pumping area (right-hand end) of the plunger R is only half that of the larger diameter portion (left-hand end) V of the plunger it follows that the quantity of oil sent forward by the plunger R equals half the quantity delivered into the chamber Q by the pumping stroke of the plunger B. At the end of the pumping stroke of the lower plunger B the motion is reversed so that this plunger then moves towards the left and again becomes a suction plunger while at the same time the portion V of the upper plunger R, also moving towards the left, acts as a pumping plunger, this portion V, moving inwardly in the chamber or barrel Q, and the valve L having been forced (by the oil forced through the passage E of the plunger A in its pumping stroke which takes place simultaneously with the suction stroke of the plunger B) into the position shown, half of the oil previously delivered into the chamber Q by the pumping stroke of the plunger B will be forced through the passage U in plunger R and out through the pipe T to the part to be lubricated.

From the above description it will be seen that the plunger R with enlarged diameter portion V is a double-acting pump. Similarly the plunger Y with enlarged diameter part X is a double-acting pump. The plungers B and A are single-acting pumps which respectively deliver oil to the chambers or barrels Q and W in which the larger area ends, V and X, of the plungers R, Y respectively work. The action above described of the plungers B and R by their pumping strokes forcing oil out through the pipe T to the part to be lubricated continues so long as the plungers are reciprocated by the motion of the cam H. The description given relates more particularly to the right-hand pump (Fig. 1) comprising the plungers B and R, but each pump being identical in action the description will also apply to the action of the left-hand pump comprising the plungers A and Y. In Fig. 1 the pumps are shown set at their full capacity of oil supply. When less oil is required to be sent forward to the parts to be lubricated the regulating screws G are screwed outwards, thus giving a later cut-off of the ports C in the plungers A, B, and the stroke of the plungers being constant it follows that any alteration to the time of cut-off of the ports C will affect the quantity of oil delivered by the apparatus. The valve L, it will be seen, is positively actuated by the oil forced into the valve chamber Z by the pumping strokes of the plungers A, B, the valve being thus free from liability to "sticking" or failure to act properly. Further, the valve is of a simple character, consisting of a cylindrical piece of suitable metal.

The Engineers' Club, Manchester.—The following debates have been arranged and will be held at the club: January 9th, "The Magneto in Peace and War," opened by Lieut.-Commander W. A. Bristow, R.N.V.R.; January 23rd, "The Empire's Metals and the German Octopus," opened by T. S. Bangham; February 6th, "Enemy Influences in Great Britain and their Effect," opened by Stafford Ransome, Secretary the British Engineers' Association; February 20th, "The Engineers' Club: What it is, and What it might be," opened by Edmund L. Hill; March 6th, "Engineering and Imperial Production," opened by T. C. Elder; March 20th, "German Banking," opened by J. Drummond Paton.

THE INTERNAL-COMBUSTION ENGINE.*

BY DUGALD CLERK, D.SC., F.R.S., M.INST.C.E.

MOTIVE power is of fundamental importance to industrial civilisation: without steam, internal-combustion, and hydraulic power it would be impossible to support at all the 46,000,000 of people now living in fair comfort on our small islands of Great Britain and Ireland. The labour of the scientific man, the engineer, and the business man, in the long run, renders possible the very existence of this large and dense population. The important part taken by us in the origin and development of steam motive power is well known, and it is generally recognised that Britain stands supreme in all that relates to steam engines from the time of the condensing engine of James Watt to the steam turbine of the Hon. Sir Charles Parsons. All the intermediate stages—expansion, high pressures, compounding, tripling, and superheating—originated in these islands. The application to pumping, mill driving, marine navigation, and locomotive engineering began and developed here. Although the credit of steam invention is conceded to us, many of our general public and some of our engineers seem unaware of the leading part taken by England in that great field of invention covered by internal-combustion engines; they imagine that in this subject we are wholly indebted to Germany, and that the work of invention here is small compared to that of the Continent. This impression has arisen because of the indefatigable propaganda of scientific engineering Germany and the distinct bias to German methods shown by some of our prominent men. We are freely given to self-criticism, and no doubt in time of peace this characteristic is quite beneficial and useful in maintaining the desire to improve; but in times of war and change it is as harmful to under-rate our own strength and achievements as it is to under-rate the power of our enemies.

In the development of internal-combustion engines we have borne our full share of pioneer work. It is true that effort both in the past and present is more uniformly distributed among the nations in this field than in steam, but we hold our own in the competition towards more perfect thermodynamic methods and machines. A very short review of the past will convince you that much has been done by England to develop engines fit for the great modern uses of stationary power production, land and water locomotion, and last, light and powerful engines for flight. The subject is one to which I have devoted much attention for the past 40 years, during which these engines have developed from mere toys of ½ h.p. to 3 h.p. to engines of the thousands of horse-power of to-day. During that time there have been produced heavy engines for stationary purposes, light engines for motor-cars and flight, and intermediate engines for ship propulsion—all with the characteristic burning of the combustible gaseous or vapour fuel within the cylinder instead of within the boiler furnace.

My interest in the gas engine—as it was then called—began at the end of the year 1876. At that date the only types of engine in operation were the non-compression engine of Lenoir and the non-compression free piston engine of Otto and Langen. In 1876 the Lenoir engine had practically disappeared from commerce: a number were at work, but the only commercial engine was the Otto and Langen. This was a cumbersome engine, which operated with great noise and much recoil, and the largest of the type in existence did not develop more than 3 b.h.p. In that year the user of motive power had but little choice. He was practically confined to the steam engine, both for small and large powers. The motive power user of to-day is in a more fortunate position. Constructors of many types of motors compete for his favour. These 40 years have seen a marvellous development of the gas engine, and an extension of the use of different fuels has caused the old title "gas engine" to disappear in favour of the more general term "internal-combustion motor," lately shortened to "combustion motor," which includes all engines known as gas, petrol, and oil motors.

The gas engine originated, as its title shows, in a form of machine adapted to burn the coal gas of our towns; for many years past other inflammable gases have been consumed, such as producer gas in its various forms, generated from anthracite, coke, bituminous coal, and waste combustible solids like wood chips, sawdust, spent tan, and cocoanut shells, also coke oven gas and blastfurnace gas; light volatile hydrocarbons are used, such as petrol and benzole; heavy hydrocarbons and sometimes coal tar. Even alcohol is applied to the purpose of actuating such engines. In 1876 the total power generated by gas engines in the United Kingdom did not exceed 2,000 b.h.p., while in 1907 the final report of the first census of production of the United Kingdom shows that factories alone had at work a total of 680,177 h.p., while agriculture employed 98,785 h.p. of gas, petrol, and oil engines. In addition to this there were in use in motor-cars and motor-cycles not less than 750,000 h.p. generated by petrol engines. The total power generated by internal combustion was thus:—

	Horse-power.
In factories, stationary gas, oil, and petrol engines...	680,177
For agriculture, stationary gas, oil, and petrol engines	98,785
For motor-cars and cycles	750,000
	1,528,962

In the United Kingdom a total of over 1,500,000 h.p. combustion engines thus existed in the year 1907.

An enquiry made in Germany in the same year showed a total of 351,000 h.p. of stationary combustion engines in operation in factories, and the total number of motor-vehicles in use was 27,026, of which about one-half were motor-cycles. The total power of the locomotive petrol engines was not more than 180,000 h.p.

The total power generated by internal-combustion was thus:—

	Horse-power.
In factories, stationary gas, oil, and petrol engines...	351,000
For motor-cars and cycles	180,000
	531,000

In Germany a total of 531,000 h.p. combustion engines existed in 1907, a little more than one-third of the similar power of the United Kingdom. The census of production of the United States of America for 1909 shows that there were in use 1,299,021 h.p. of gas and gasolene engines for the stationary work of manufactures and mines. Nearly 115,000 motor-cars were produced in that year; this, with the vehicles in use, required engines of a total of about 1·2 million h.p. Total combustion power for the United States was certainly not short of 2·5 million h.p. The internal-combustion power in these three countries during 1907 and 1909 was:—

		Million horse-power.
1909.	United States of America	2·5
1907.	United Kingdom of Great Britain and Ireland	1·53
1907.	Germany	·53
		4·56

—over 4½ million h.p.

Allowing for the increase of Britain and Germany from 1907 to 1909, a probable value for the total combustion power of the three nations in 1909 is 5,000,000 h.p. In 1909 France had 46,000 motor-cars in use of an average of about 13 h.p., or a total of 598,000 h.p. The power of stationary combustion engines in France is not available, but the four countries show a total of at least 5¾ millions in 1909. This figure does not include oil and petrol engines used for marine purposes, which probably brings the total up to 6,000,000. In 1909, then, we find at least 6,000,000 h.p. of gas, oil, and petrol engines in the world—a truly great development since 1876. In the year 1909 America led the world in the power of such engines at work, Great Britain came second, and France and Germany were nearly equal with the third place; and although great expansion has taken place in all these countries, Germany still retains the same relative position—America and England still lead.

In addition to internal-combustion all these engines have another feature in common—all compress the working fluid before combustion; some compress an inflammable mixture and fire the compressed mixture, producing a mild explosion with a strictly limited possible rise of pressure; some compress

* Paper read before the Royal Society of Arts, November 29th, 1916. First delivered at Newcastle-on-Tyne, September 4th, 1916, at the meeting of the British Association.

air alone and then mix at the temperature of compression the inflammable gas or vapour and ignite as before; and some compress the air charge so highly that on the injection of oil fuel in a state of very fine spray the heat of compression causes the ignition of the spray as it enters the cylinder—such engines do not produce an explosion; the pressure within the cylinder never exceeds the pressure of compression or the pressure of the compressed air sometimes used to pulverise or disperse the liquid oil.

The engines operated by explosion are called constant-volume engines, and those actuated by expansion, due to flame, constant-pressure engines. Constant volume and constant pressure define the thermodynamic characteristics of the engines, but the mechanical cycle adopted to carry out in practice the necessary charging, compressing, igniting, expanding, and exhausting operations are varied. Two mechanical cycles are in general use: in one the motor piston and cylinder alternately act as pump and motor, so that four single strokes are necessary respectively for charging, compressing, expanding after igniting, and exhausting; in the other these operations are performed in two single strokes of a piston; air or the charge, however, has to be pumped and lightly compressed by a separate lighter piston or by the front of the motor piston. All existing gas, oil, and petrol engines, whether light or heavy, operate according to one of these cycles—the majority of engines in accordance with the 4-stroke system.

This feature of compression before ignition is necessary in order to provide an economical engine expanding the gases of explosion in the most favourable manner and at the same time producing large power for small bulk. This mode of operation was the invention of an English engineer so far back as 1838. It will be found described in Wm. Barnett's Patent No. 7615 of 1838, where he gives full particulars of a double-acting internal-combustion engine having separate air and gas pumps, which supply a charge under light pressure to a motor cylinder, in which there acts a piston over-running a large port in the middle of the stroke. The charge displaces the products of the previous explosion, and is compressed by the return of the piston into a combustion space left at the end of the cylinder. Barnett had fully realised the advantages of compression before ignition, and proposed in accurate detail an engine closely resembling modern two-stroke engines. He was the originator of both the compression idea in its present form and the 2-stroke-cycle of operation.

The first German engineer to appreciate the advantages of compression was Gustav Schmidt, but he did this 23 years later than Barnett, in a paper read before the Society of German Engineers in 1861. Schmidt states, criticising the Lenoir non-compression engine: "The results would be far more favourable if compression pumps, worked from the engine, compressed the cold air and cold gas to three atmospheres before entrance into the cylinder; by this a great expansion and transformation of heat is possible."

Million, a clever Frenchman, in his Patent No. 1840, of 1861, shows that he had exceedingly clear ideas of the advantage of compression; he evidently considers himself as first to propose its use in a gas engine, apparently unaware of the existence of Barnett's engine which I have just described. He claims the exclusive right to use compression in the most emphatic language. One engine described is exactly what Schmidt asked for. Separate pumps compress the air and gas into a reservoir, from which the movement of the motor piston, during a portion of the stroke, withdraws its charge under compression. Ignition is accomplished by the electric spark, and the piston moves forward under the high pressure produced. He also describes a compression engine in which the motive cylinder is made longer than necessary, in order that the piston shall always leave between it and the end of the cylinder a space such as one-fourth or one-third of the volume generated by the motor piston. Here he resembles Barnett and the modern internal-combustion engines.

M. Alph. Beau de Rochas, a brilliant Frenchman, in a remarkably clever pamphlet published in Paris in 1862, discusses the conditions of economy in gas engines using compression with reference to volume of hot gas and cooling surface to which they are exposed. He states that four conditions are necessary in order to obtain the maximum economy in a compression explosion engine: (1) The greatest possible cylinder volume with least possible cooling surface; (2) the greatest possible rapidity of expansion; (3) the greatest possible expansion; and (4) the greatest possible pressure at the commencement of the expansion.

He therefore reasons that a large cylinder is necessary, and the time of exposure to cooling should be as short as possible and piston speed high. He considers that the sole arrangement capable of meeting the conditions is a single cylinder engine having the following series of operations: (1) Suction during an entire out-stroke of the piston; (2) compression during the following in-stroke; (3) ignition at the dead point and expansion during the third stroke; (4) forcing out of the burned gases on the fourth and last return stroke.

The ignition he proposes to accomplish by increase of temperature due to compression. This he expected to do by compressing to one-fourth of the original volume. He also proposes a double-acting engine of the same type with piston rod and stuffing-box. Beau de Rochas' proposal had to wait for 14 years before it was put into successful practice. The late Dr. N. A. Otto, of Cologne, succeeded in overcoming the practical difficulties in the year 1876, when he produced the first commercially successful gas engine utilising the idea of compression before ignition, first proposed 38 years before by the English engineer Barnett, applied by the means of the cycle of operations due to Beau de Rochas. The modern 4-stroke engine was thus the outcome of the English, French, and German brain. The world, however, remains deeply indebted to the late Dr. Otto, whose ability and pertinacity, applied at the crucial time, produced an engine which marks an epoch in the advance of internal-combustion motors. Dr. Otto deserved his success; he had fought long and hardly for it. He was born at Holzhausen in Nassau in 1832; he began his work on gas engines in 1854 at 22 years of age; attained his first success—the Otto and Langen engine already referred to—in 1866; and made his epoch-making advance in 1876. He applied his whole life to the study and development of the gas engine, and died in the year 1891 at the age of 59, after 37 years devoted to the problems of internal-combustion.

Although in 1861 Schmidt in Germany and Million in France described compression engines with separate compressing pumps, no 2-stroke engine appeared in public till 1879, when I exhibited my first compression gas engine at the Kilburn Show of the Royal Agricultural Society of England. This engine was patented in 1878 (Patent No. 3045). It had two cylinders, a pump, and a motor, each of 5in. diam. by 8in. stroke. The pump compressed a mixture of gas and air into a reservoir at the full pressure required; the mixture was admitted to the motor cylinder during the first part of its stroke, cut off by valve, and ignited by an incandescent platinum igniter, the piston driven forward by the explosion, and after expansion the return stroke of the piston discharged the exhaust gases. This engine was heavy for its power, and it was subject to the difficulty of back ignition into the reservoir, so that it was not placed on the market. The engine gave 3 b.h.p., however, for many months, and it is believed to be the first compression engine ever run giving one impulse for every two strokes of the motor piston.

The engine best known by my name was patented by me in 1881 (No. 1089 of 1881). It resembled Barnett's of 1838 in compressing within the cylinder and giving one power impulse for each double stroke; but it differed in applying exhaust ports at the out end of the stroke overrun by the piston to time exhaust and charging. It further differed in coupling the pump or displacer cylinder to the main crankshaft, instead of driving at twice the number of revolutions by gear wheels.

At the time when I was inventing, designing, and experimenting with 2-stroke engines in Glasgow, a Northumberland man, the late Mr. James Robson, was busily at work on compression. His first patent is dated 1877, No. 2334. It describes an engine of the non-compression type; but he produced a 2-stroke engine with compression, under patents dated 1879 and 1880. Messrs. Tangye, of Birmingham, produced an engine with Mr. Robson, which was first exhibited in public by them at the end of 1880. In this engine the front end of the cylinder was enclosed and used as a pump to force a mixture of gas and air into a reservoir at a pressure of about 6lbs. per square inch above atmosphere; the piston over-ran ports in the

cylinder, but the exhaust was not timed by it; a separate valve was used which controlled the exhaust.

Siemens in 1861, and Brayton in 1873, had proposed constant pressure engines, in which the front end of the cylinder was used to compress the charge which was utilised on the other side of the piston to produce power by combustion and expansion; but Robson was first to propose the use of the front to compress lightly the charge for the compression engine of the explosion type. The 2-stroke or impulse-per-revolution engine was thus the result of the work of the English engineer, Barnett, 1838; the French engineer, Million; and the German engineer, Schmidt, in 1861; and British engineers, Clerk and Robson—Clerk by his 1878 and 1881 engines, and Robson by his 1879 and 1880 engines.

Mr. Robson's son, Mr. James Robson, of Messrs. Tangyes, Ltd., published an interesting booklet last year describing his father's early work, from which it appears that Robson experimented with gas engines of different types from the early date of 1855, and he rightly claims priority for his father as the inventor of one type of 2-stroke engine—that in which all the pumping and motor actions are performed by one piston in a single cylinder. Undoubtedly, Mr. Robson was very early in the field, and his work was most meritorious; but the existence of Barnett, Million, and Schmidt prevented any later inventor from claiming the whole idea of impulse every revolution. Robson and Clerk both invented modifications which made the 2-stroke idea practicable; but as the 4-stroke cycle had been invented by Beau de Rochas, so the 2-stroke idea was likewise proposed by the earlier inventors.

Messrs. Sterne & Co., engineers, of Glasgow, built and sold large numbers of Clerk type 2-stroke engines, and Messrs. Tangyes, of Birmingham, a large number of Robson engines. The test of use and time, however, proved the 4-stroke engine to be best adapted for most purposes, and by far the largest number of internal-combustion engines in existence operate according to this cycle.

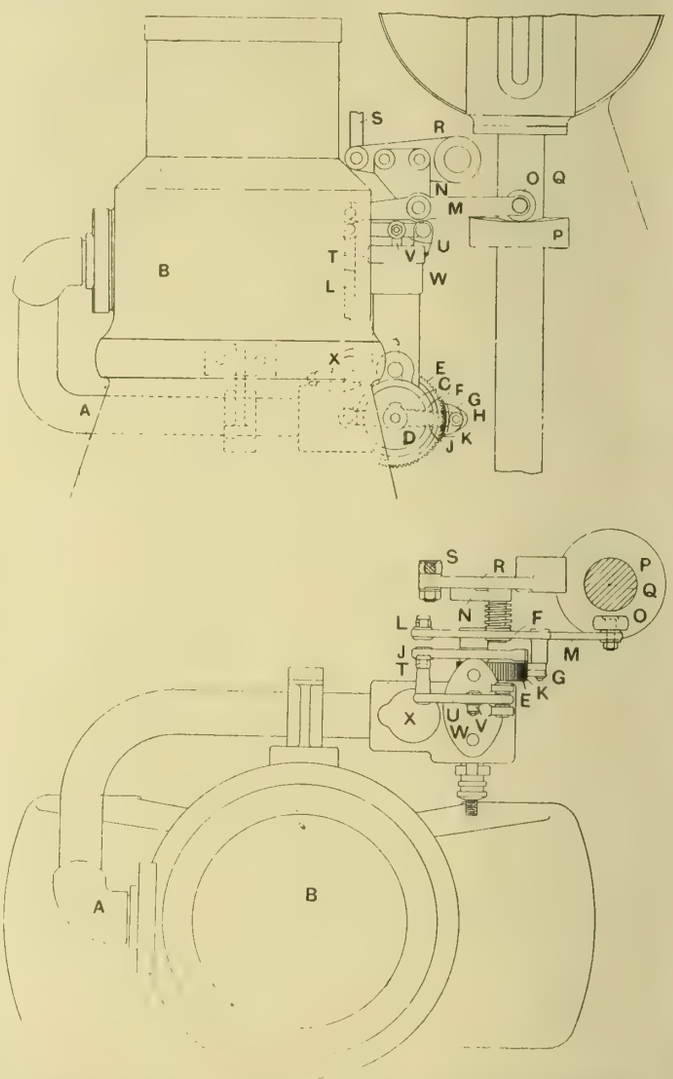
Many of the larger gas engines in Germany and America operate upon the Clerk modification of 2-stroke compression engine as adopted by Messrs. Kœrting, of Hanover, and their licensees. In the enquiry made in Germany referred to already, it was proved that 260,000 b.h.p. was produced in that country in the year 1907 by 4-stroke engines, and 91,000 b.h.p. by 2-stroke engines.

A modification of the Robson 2-stroke engine was made in England by Mr. Day in 1891, in which a crank case was used as the pumping chamber, and the piston, by means of three cylinder ports, performed all the necessary valve operations. This form of engine is largely adopted in America for launch propulsion; some motor-cars also used it. An increasing use is being made of 2-stroke engines for large gas and oil engines, and this type is now firmly established and shares the field with 4-stroke engines; both have advantages on some points and disadvantages in others.

(To be continued.)

AIR-SUPPLY REGULATING DEVICES FOR INTERNAL-COMBUSTION ENGINES.

MESSRS. Cole, Marchent, & Morley, Ltd., Prospect Works, Wakefield Road, Bradford, have recently patented the device shown in the accompanying plan and elevation for regulating the supply of air to Diesel and similarly actuated internal-combustion engines using liquid fuel, according to the load on the engine. In this device there is arranged in the inlet pipe A to the compressor B a throttle valve C. Connected to the spindle D of this valve is a semi-circular rack E. Loosely mounted on the spindle D of the valve is an arm F carrying two oppositely directed pawls G which are pressed by spring means H towards the rack. On a further arm J also loosely mounted on the spindle D is carried a shield K which is normally located between the pawls G and the rack E. The pawl arm F is connected by a link L to a lever M which is mounted, on a movable fulcrum-plate N, and at its outer end carries a roller O which bears on a cam race P on the governor spindle Q whereby a continuous oscillation is imparted to the arm F and pawls G. The means for forming a movable fulcrum for the lever M consist of the plate N, which is connected to a lever R mounted on any suitable stationary part of the engine, while the outer end of this lever R is connected by the rod S to the governor mechanism to rise and fall therewith. From this arrangement it will be seen that, as the speed of the engine tends to vary owing to varying loads, the rod S will move and so alter the position of the movable fulcrum N of the lever M which is operated by the cam race P, causing the path through which the pawls G are oscillated to be also altered, which will enable the pawls to act on the rack E at one or other end of the shield K and so adjust the valve C. The shield arm J is connected up through the rod T and lever U to the plunger rod V of a pressure plunger in the cylinder W so that the alteration of the pressure in the air bottles and air pipe, caused by the adjustment of the valve C



AIR SUPPLY REGULATING DEVICE FOR INTERNAL-COMBUSTION ENGINES.

leading to the compressor, will cause the shield K to move in its path between the rack E and the pawls G. The adjustment of the parts is such that when the pressure has reached the desired point to enable the correct amount of air to be injected into the cylinders of the engine for the then load, the shield will have moved into such a position as to prevent the pawls from acting further on the rack, until such time as the load on the engine is altered. It will be seen that the supply of air to the compressor and therefore to the cylinders of the Diesel engine is controlled through a ratchet and pawl device, in the first place through the governor and in the second place through the pressure in the air bottles. The inlet to the compressor is provided with means such as a cap X for admitting the full quantity of air thereto when desired as for starting purposes independently of the throttle valve.

The Iron and Steel Institute.—The dates fixed for the general meetings of the Iron and Steel Institute in 1917 are: Annual meeting, Thursday and Friday, May 3rd and 4th; autumn meeting, Thursday and Friday, September 20th and 21st.

DIESEL ENGINE USERS' ASSOCIATION.

AT the November meeting of the Diesel Engine Users' Association several new members were elected, and a long list of consulting engineers, manufacturing firms, and others interested in Diesel engine work, but not qualified for full membership, were accepted as "subscribers" to the association. This new class of "subscribers" are entitled to receive copies of the reports of proceedings and other information and particulars circulated by the association. The president (Mr. Geoffrey Porter) announced that the committee's report on "Air Compressor Explosions and Troubles" with their recommendations on the subject had been finally revised, and that it would be printed and circulated to the members and subscribers. The Honorary Secretary gave particulars concerning several types of distance thermometers for use on air compressors which he had collected from instrument makers, with information concerning cost of installation, &c. Mr. George B. Vickers then read the following paper on "Piston and Small End Lubrication in Diesel Engines":—

PISTON AND SMALL END LUBRICATION IN DIESEL ENGINES.

BY MR. GEORGE B. VICKERS.

The subject to be discussed this afternoon is "Piston and Small End Lubrication." Dealing first with lubricating troubles, these may be placed under two headings, either unsuitable lubricating oil or faulty design.

Lubricating Oils.—The lubricating oils should be carefully chosen. Pure mineral or hydro-carbon oils are undoubtedly the best. They contain a much smaller percentage of acid than animal or vegetable oils. The deposit from mineral oils is more easily rubbed off the bearing surface when the load comes on, than animal or vegetable oil deposits. Many compound oils are good, but although they may be carefully blended originally, there is, after repeated use, sometimes evidence of disintegration, and they are liable to give a gummy deposit. It has been found by many engineers on Diesel installations that oils which are otherwise very suitable are the cause of considerable liner wear. The best test of lubricating oil is on the air compressor. If the oil causes pitting on the compressor valves and shows an acid scouring action on the valves in the air bottle beds, the engineer may expect the main cylinder liner wear to be excessive. Regarding the amount which may be taken as average liner wear, figures taken from a number of engines give a mean wear of ·010in. to ·012in. per 1,000 hours' run, when the engine is heavily taxed. There are many means of reducing this liner wear but this subject is not under discussion. The lubrication requirements of the small ends and the pistons are contradictory. For pistons an oil with a moderate viscosity of say 130 to 180 at 140° Fah. gives good results, whilst an oil with a good viscosity of say 400 to 500 at 140° Fah. is best for small end lubrication.

Again, the type of engine and the temperature of the engine room should be a governing factor in the class of oil used. For enclosed type engines thicker oil is required than with the open type, as the temperature inside the crank case is much higher than on open type engines. Remarkable experiments showing the importance of using fairly thick oil for piston lubrication on enclosed engines were made by Messrs. Hick, Hargreaves, & Co., Ltd., during the last 12 months. A number of naval high-speed engines were constructed and tested under load. Difficulty was experienced in using the thin oil provided, which had a viscosity of 110 at 140° Fah., and was almost like paraffin on the piston after an hour's run. Thicker oil of the quality used on our usual Diesel work was used having a viscosity of 140 at 140° Fah. in place of the thin oil, and the fuel consumption, which previously had never been lower than ·45lb. per b.h.p. hour, was reduced to ·419lb., effecting a saving of 15s. in a six hour trial run.

The lubricating oil used for pistons or small ends should not emulsify, so that if any water drops in the crank pit, it can afterwards be separated. Most mineral oils are easily separated from the water. When a different oil is used for top end lubrication than is used for the piston, care should be taken that the oils will blend. Some oils are impossible to compound. On average engines the quantity of lubricating oil used is kept as low as possible by using new oil on the small ends only, and filtered oil on the other parts. This filtered oil has advantages, as after running and filtering the bituminous matter in the oil is eliminated. Filtered oil should not be used too often on the pistons, as its viscosity gets too low for this work. The original method of lubricating the piston by a single stem leading to a belt encircling the liner, and from thence through small holes in the liner, is a poor method. The oil gets congealed and carbonised and the belt eventually gets choked and there is always the chance of water getting into the cylinder past the belt, a fault most difficult to overcome. On engines where the belt lubrication is used, the belt should be flushed out with paraffin every time that the pistons are withdrawn, or perhaps even once a week.

The usual method of piston lubrication is through four or six stems or quills leading through the water-jacket to the liner. The customary method has been to connect each of the quills by a common feed pipe, past a back-pressure valve, to the single lubricating pump. Many engineers now insist on having a separate feed to each quill, *i.e.*, they have a six or eight feed lubricator fitted for each cylinder. This method, of course, is more costly, but is not very expensive, and is undoubtedly the better plan. Many piston seizures have been caused by faulty arrangement of lubricating piping and leaky back-pressure valves. The lubricating pumps for piston lubrication are, in the majority of cases, driven from the cam shaft, and so are placed much higher than the quill line. The result is, after a short stoppage, the feed piping has been drained, and unless there is wasteful flushing through, the piston does not receive any lubrication for a few minutes after starting. Some engineers have overcome this difficulty by curving the feed pipe so that it is unable to fully drain itself; others have fitted small valves, which are shut off when the engine stops. A better plan which is now adopted by one or two firms is to have the lubricators fixed well below the lubricating belt line and worked off the indicator gear or the vertical shaft, thus ensuring that the pipes are always charged. When this better position for the lubricating pumps is adopted, the arrangement is often lacking in completeness. The pump should be fitted with a flushing arrangement in case of necessity, and preferably sight feeds with regulating valves. The check valve in the lubricator pipe is of greater importance than many attendants seem to think; it should be well designed and periodically examined to ensure that there is no bituminous matter holding the valve up and interfering with the supply. Mr. Lyle, of Messrs. Hoffmann's, was able to avoid trouble from valves sticking up, by altering his piping slightly, so that the check valve was vertical, and so assisted by gravity in keeping on its seating. In quite a number of engines the check valves are inverted and are probably the seat of many troubles.

I mentioned that the usual method adopted to introduce the lubricating oil to the piston and liner surface was by means of quills. The method of securing these is sometimes the cause of trouble. Some makers prepare a tapered hole in the liner, and the quill has a rounded nose (sometimes of copper), and the quill is screwed home tight through a tapped hole in the water-jacket. When the parts get warm and expand, these quills have been found to act as struts, and have caused piston seizures immediately opposite to the lubricating holes. An improved method is to have the quill screwed into the liner, a plain hole in the water-jacket, and an external joint made. The telescopic quill, as made by one well-known British firm, is an improvement over either of the previous methods, but is capable of being simplified.

It is usual to introduce the lubricating oil between the first and second rings when the piston is at the bottom of its stroke, but some makers have not done this and have not found any difference. It is advisable to slightly countersink the lubricating holes in the liner on the liner surface to avoid any burring over. Oil grooves leading both left and right from each oil hole, greatly assist lubrication. The grooves should have a slight fall leading away from the holes and should overlap one another. Some makers have not adopted this direct means of lubricating the piston through quills in the liner, but have relied on what is termed the "splash system." The pistons with this system have skirts which protrude well beyond the lower edge of the liner, at the bottom of the stroke. The piston relies on the splash from the bottom end of the connecting rod for its lubrication. The manufacturers who have used this system have found it effective on pistons up to 14in. or 15in. diam., but when tried on larger type engines actual users have found by bitter experience that this splash system is not reliable. The system is really only suitable for small engines, and its chief drawback is, that lubri-

cation cannot be regulated, is most uncertain, and there is a tendency to wastage.

Top End Lubrication. — Phosphor-bronze bearings are usually adopted for the top end bearings. Different manufacturers have tried white metal lined top end bearings, but have usually come to the conclusion that the pressures are too great for white metal to be successful. The wear on phosphor-bronze bearings is seldom more than ·001in. per annum, whilst white-metal bearings, according to the quality, may show more wear than this in one week. It is impossible to give a definite clearance allowable at top ends. If white metal is used, no clearance should be allowed, after running the engine light for a time, the bearings then run quite satisfactorily. When a phosphor-bronze split bush is used, the average clearance is ·003in. vertically and ·006in. at each side. If the bush is solid, more clearance is required, usually ·006in. to ·008in. vertically, and ·008in. at the sides. Much seems to depend on the material adopted for the bearing and the pin. With some classes of steel used for gudgeon pins, a greater clearance is required to allow for distortion than with other steels. The gudgeon pins should be fully case-hardened, at the ends as well as on the bearing surface. A case occurred recently where the pin had been left soft at the ends, and when tapping the pin into the piston, the end of the pin was bulged, and when forced into the piston, it split the boss in two places.

The position of the gudgeon pin in the piston is very important. If the pin is located too low, the piston will tend to heel over at the top when maximum compression pressure occurs; similarly, if the pin is located too high, the piston will tend to heel over when the maximum working thrust occurs. The ideal position of the pin is at a mean between this permissible high and low point. A good long skirt is advisable to act as a guide, and to reduce the pressure per unit area due to thrust. The length of guiding surface on the piston should be 1·4 to 1·6 times its diameter for slow-speed engines, but may be reduced to 1·2 times the diameter for high-speed engines.

Many of the methods adopted for lubricating the top end bearings do not appeal to the British engineer. A good designer would only adopt them as a last extremity and then only with great diffidence. Still, strange to say, the methods are effective. Taking first the scraper system, two grooves are cut on the bearing surface of the piston, the top of the grooves entering the small circular groove usually turned on the piston below the lowest ring in the top nest, the grooves then take the form of a half spiral gradually decreasing in width until they are opposite the ends of the gudgeon pin. Holes are then led through the piston to the centre of the pin. The oil gathered in one groove leads to the large diameter end of the pin and the oil from second groove is led into the small diameter end of gudgeon pin. Two holes are led from the centre of pin to the top bearing surface in the usual manner. This method, depending as it does on collecting the oil remaining on the liner walls after the rings have scraped the majority off, seems a very haphazard method, but it is quite effective for pistons up to 24in. diam.

In the second, the banjo system, the oil is led into a banjo on the side of the crank and the centrifugal force causes the oil to flow into a small receiver, having a steel ball and cage fitted at every revolution of the crank, the ball, having a small lift, is thrown up by its inertia, and allows a small quantity of oil to pass up the pipe leading to the top end; as the ball falls on to its seating it acts as a retaining valve. Without a knowledge of the effectiveness of this system any engineer would be justified in expecting that at least a special quality of oil, of the "Monkey" brand, which would climb up the pipe, would be necessary for this system.

The third, and most general method of top end lubrication is to have one or two slots in the piston which pass over the leads from the oil supply pipes and holes leading from the bottom of the slots through the piston to the centre hole in the gudgeon pin. Several holes lead from this central hole in the pin to the bearing surface. This method being the one most frequently adopted, it is perhaps desirable to mention a few useful hints regarding it. In the first place, it is preferable to have two slots in the piston, one midway between crankshaft centre line and cross centre line on the front side of piston, and one directly opposite, so that whichever side of the liner the piston is thrust against, one of the slots is able to scrape the maximum quantity of oil from the liner. This is also desirable because the more sources of lubrication there are the better chance there is of keeping the bearing cool. Two quills, of course, are required to deliver oil from the pump through the liner at points in line with the slots in the piston. Improvement may also be made in many cases in the shape of the slot. The slot is best when V-shape in section, and the top and bottom should be undercut at about 45°, the scraping edges being left moderately sharp; a sluice should also be cut to connect the top of the slot to the circular scraper groove cut in the piston to take advantage of the oil scraped off the walls by this groove. The angle at which the hole is drilled leading to the centre of the pin should be fairly steep to assist the flow. The slot should be fairly long, but care should be taken that a moderate head of oil is allowed between the bottom of the slot and the top of the gudgeon pin. The oil hole should have a large countersink, both in the piston, and also when it enters the pin. The hole in the centre of the pin should be at least 1¼in. diam. for a 6in. pin, as it acts as a reservoir for the oil. Two holes at least should be drilled from the top of the pin to the centre, one close to each end of the bearing surface; these holes may be drilled at 30° to a vertical centre line. Both these holes should lead into a longitudinal groove on the top surface of the pin. These grooves should have well rounded edges, to assist the oil to escape. In the case of white metal top end bearings, when there is little clearance to allow the oil to work its way over the pin surface, the best method of spreading the oil is by two half spiral grooves cut in the white metal.

On medium and high-speed engines a complete service of forced lubrication solves lubrication difficulties. Of course, this means having the engine fully enclosed. Regarding the top end lubrication, the practice of fitting a lubricating pipe leading from the bottom to the top end is to be deprecated. Any external pipes tend to come loose at the joints and get broken. It is much better to have the oil passage up the centre of the connecting rod. When a priming system of lubrication is not provided, a small ball valve fitted in a cage in the hole at the bottom end of the connecting rod acts as a retaining valve when the engine is shut down and prevents the oil from draining away from the top end.

Although the forced lubrication on all the bearings effectively solves the problem of top end and piston lubrication, the system has disadvantages. Unless manufacturers have taken special precautions, it is probable that the piston will receive too much lubrication. The oil is thrown from the bottom end bearings on to the liner walls, and when the piston is on its suction stroke the slight pressure in the crank chamber tends to force the oil past the relaxed rings, the result being that the lubricating oil is burnt and very peaky indicator cards are obtained, showing a maximum pressure frequently 100lbs. to 150lbs. above compression pressure. The high consumption of lubricating oil has retarded the progress of the enclosed type of engine. We have overcome the difficulties, first, by guarding the bottom end bearings to avoid splash on to liners; secondly, by preventing the oil from creeping from top end bearing along the gudgeon pin keyway on to piston surface; thirdly, by providing scraper grooves on piston with return ducts to inside; fourthly, by dissipating the vapour in crank chamber, this vapour tending to get past the rings on suction stroke.

The common method of withdrawing the oil vapour in the crank chamber is to take the air compressor suction or the main cylinder suction from the chamber. In our opinion this causes dirty valves, is wasteful, and in a few cases has proved to be dangerous. We find that the vapour is most effectively withdrawn by a belt-driven extraction fan, and we lead the gases to a baffle box where they are condensed, thus recovering the oil which by other methods is burnt. The vapour is mainly caused by the oil being splashed on the inside of the piston crown, and if the crown has an oil guard fitted the vapour is considerably reduced.

A discussion followed, and Mr. W. Fennell gave some information concerning enquiries he had made in regard to the possible use of deflocculated graphite, and special graphite preparations for the lubrication of Diesel engine cylinders. Apparently, this form of lubrication had not been tried in many cases, and the information which he received from a few quarters was not sufficient to justify his making any experiments with it on the engines under his control. He also referred to the increased sulphur contents of certain fuel oils which were now being used, and it was found that these reacted on the lubricating oil, especially if this was com-

pounded with vegetable oils, causing a sticky deposit, analogous to vulcanised bitumen, which destroyed the lubricating properties of the oil. He considered that it was important that compounded oils should not be used for cylinder lubrication, and that for this purpose a pure mineral oil only should be made use of. The real difficulty in lubricating a Diesel engine cylinder was that there is no oil which stands the temperature of burning gases. An ideal lubricating oil would leave no deposit when burnt away. He expressed the opinion that the most successful Diesel engine of the future would have a crosshead. He also strongly advocated separate lubricators for each point to be lubricated.

In his reply to the discussion Mr. Vickers agreed that sulphur would certainly have a bad effect on most compounded oils, but that it would have no effect on a pure mineral oil. If there was any sign of acid action in a lubricating oil, it was not suitable for use on the engine. In vegetable oils the acid property was frequently 3 per cent., whereas in mineral oils this was very seldom above ·3 or ·4 per cent.

THE CARBONISATION OF COAL, WITH BY-PRODUCT RECOVERY.*

BY S. B. BILBROUGH.

THE carbonisation of coal is becoming of increasing importance in all coal-bearing countries, and of late years the importance of these industries is being much more discussed, and very much more interest is taken in their development. The cheapness of coal has been the chief drawback to its conservation and prevention of its waste. An important discussion is at present going on in Britain on the wastefulness in the coal industry—a discussion which seems to have matured after 50 years of waste. I have been asked, "Tell me what is in my coal," and a bituminous sample of coal has been submitted. The reply might well be, "Almost everything is in your coal, and it does not particularly apply to your coal, but to every bituminous coal." But the question as to which of the constituents it will pay best to extract or produce from the coal is a very different proposition, and the answer becomes at once limited and narrow, and is a different answer for different countries and different localities in the same country.

The commercial products of coal as produced in carbonising plants are: (1) Power gas (primary product). (2) Coke (primary product). (3) Lighting gas (primary product). (4) Sulphate of ammonia (by-product). (5) Tar and its distillates (by-product).

Three distinct plants, employing different methods, are in use for obtaining these products, viz.: (1) Gas producers. (2) Coke ovens. (3) Town gasworks. There are no other methods in use to-day than the above-named three for carbonising coal with by-product recovery, and there are no plants in existence which make sulphate or tar as a primary product. The three plants, viz., gas producers, coke ovens, and gasworks, can only produce efficiently their own special products and by products. It is very important to bear this in mind. These three systems of carbonisation separately operated would give the following products:—

I.—GAS PRODUCERS.

Primary Product.—Power gas for heating, for generating steam in boilers, for driving gas engines. The volume of gas per ton of coal is enormous—about 150,000 cub. ft.—and the calorific value is low—about 140 to 160 B.Th.U. per cubic foot.

By-products.—Sulphate of ammonia, in large quantities. The maximum ever obtained from the nitrogen in the coal is obtained by this system, and amounts to 80lbs. to 140lbs. sulphate per ton of coal gasified, depending on the nitrogen content of the coal.

Tar, in small quantities, is also obtained, but is of no value for distillation purposes, and the less there is of it the easier the plant is worked.

No other products can be made by these plants. There is no motor spirit, no valuable oils, and no coke to be obtained from this system of carbonisation. The production of sulphate is so high from these plants that they might equally be termed sulphate plants as power-gas plants.

II.—COKE OVEN PLANTS.

Primary Product.—Good metallurgical coke, 60 per cent. to 70 per cent. of the weight of the coal, is obtained.

By-products.—Surplus of good high grade gas, which can be used for lighting or steam raising.

Tar, of good quality, and used for distillation into products too numerous to mention, amount to 8 galls. to 10 galls. per ton of coal.

Sulphate of Ammonia, in small quantities, about 20lbs. to 25lbs. per ton of coal.

The distillation of the tar is usually carried out by separate companies, the chief products being pitch, road compo, creosote, carbolic, light naphthas, benzol, dyes, and numerous other products in small quantities.

III. GASWORKS.

Primary Product.—Lighting gas of high grade, about 10,000 cub. ft. to 12,000 cub. ft. per ton of coal, and having a calorific value of about 600 B.Th.U. per cubic foot.

Tar.—About the same as for coke ovens in quantity and quality.

Sulphate.—About the same as for coke ovens.

Coke.—About 60 per cent. of coke is produced, known as gas coke. The tar is distilled by separate companies, giving the products mentioned under II. (coke ovens).

This illustrates briefly the distribution of the various products contained in coal to the three systems by which they are produced. These primary industries may be termed "key" industries, and are of the highest importance for any coal-bearing country to possess, as dependent on them are numerous other industries.

* From a paper read before the South African Institution of Engineers, and reproduced from the Journal of the Institution.

WOLFRAM FROM THE MALAY STATES.

THE demand for tungsten ores for the manufacture of war material has prompted enquiry into the Empire resources of these ores. In the last report of Mr. W. Eyre Kenny, Senior Warden of Mines, Federated Malay States, it is stated that the total tonnage of tungsten ores exported from those States in 1915 amounted to 291 tons, in 1914 to 261 tons, and in 1913 to 225 tons. The greater quantity was low-grade ore, and carried less than 65 per cent. of tungstic acid. Tungsten ores aggregating 407 tons were imported from other countries and re-exported after treatment at separating works in the States, but are not included in the above-quoted figures. There is nothing to show to which countries the tungsten was exported. The value of wolfram alone exported from the Federated Malay States in 1915 was £32,174. It is not generally realised that tungsten ores do not occur in the Federated Malay States in defined deposits, and that by far the greater bulk is found in small quantities, irregularly intermixed with tin ore and valueless matter. These facts render it impossible to obtain any large increase in output. The ore is also mainly of a low grade, which is not a favourable factor. Every effort has been made by the authorities to stimulate production, however. Export duty has been suspended, and special terms are given to prospectors and as regards mining rights. Turning to the statistics of the Straits Settlements, more light is obtained with regard to the supply of wolfram from the Malay Peninsula and Archipelago. The total value of the exports for three years was as follows: 1913, £74,638; 1914, £54,130; 1915, £69,900. Wolfram was imported into the Colony from the following countries:—

	1913 Tons.	1914 Tons.	1915 Tons.
Burma	115	28	22
British Malay States	268	230	220
Siamese Malay States	270	179	266
Dutch Islands	—	—	18

It is interesting to note to which countries the wolfram was exported, and the principal purchasers are given below:

	1913 Tons.	1914 Tons.	1915 Tons.
Belgium	21	—	—
France	129	103	182
Germany	527	307	—
United Kingdom	5	76	400

It should be explained that the excess of exports over imports is not due to the mining of wolfram in the Straits Settlements, but to its extraction from the tin ore sent for treatment to the great tin-smelting establishments in the Colony.

TESTS OF A MODERN TOURING-CAR ENGINE.

BY G. L. GUILLET, M.SC.

This report contains the results of tests made by the Mechanical Department of the Faculty of Applied Science, Queen's University, Kingston, Ontario, during the season of 1915-1916.

The engine was a six-cylinder $3\frac{3}{4}$in. by 5in. 1916 model, Buick automobile engine, with overhead valves, loaned to the

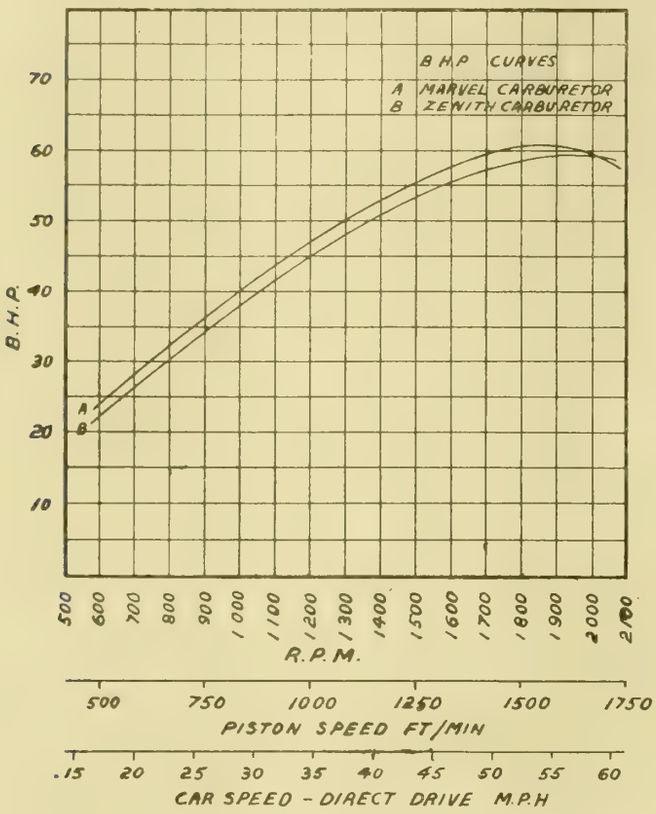


Fig. 1.

college for testing purposes by the McLaughlin Motor-car Company of Oshawa, Ont. This is a stock motor from the "D55" model car, and no changes of any kind were made in the standard equipment, excepting the substitution during part of the tests of a Zenith carburetter for the Marvel carburetter, which is usually used on this motor. The A.L.A.M. or S.A.E. rating of the motor is 33·7 h.p.

Purpose of the Tests.—The objects aimed at in making these tests may be briefly summarised as follows: (1) To obtain the power output and torque of the motor at various speeds, with wide open throttle. (2) To determine the fuel consumption of the motor at various speeds and loads with the best carburetter adjustment that would give steady running under all conditions likely to be met with in service. (3) To compare the efficiency and power output when using the Zenith and Marvel carburetters. (4) To determine the power lost in friction and used up in driving the ignition dynamo fan and centrifugal pump, &c. (5) To determine the efficiency of the transmission on the indirect drives.

Apparatus and Testing Methods.—A No. 2 Froude water dynamometer was used for absorbing and measuring the power developed. Speeds were taken by means of a speed counter attached through a reduction gear to the brake shaft. A tachometer was used to adjust the speed, but the more accurate readings of the speed counter were used in all calculations. The fuel was measured volumetrically in calibrated glass cylinders. Tests were of such duration that the fuel reading may be considered as accurate to within 1 per cent. Checking tests showed results agreeing within this limit in nearly all cases. The cooling water temperature at inlet was approximately 50° Fah. in all tests. The flow was regulated so as to give an outlet temperature of 160° to 170° Fah. in all tests. The throttle arm was provided with a tapered pin, which, fitting into the holes on a plate attached to the engine frame, made it possible to fix the throttle accurately on any required position, and to bring the throttle back to a position previously used, when desired. All tests were made with the fan, pump, and ignition dynamo driven by the engine. The brake horse-power as calculated are therefore the net horse-powers as delivered to the drive shaft of the car.

Maximum Power Tests.—The result of the maximum power tests using the two carburetters is shown in Fig. 1. It must be noted that for the Marvel tests a "maximum power" setting of the carburetter was used. The Marvel "maximum power" setting, however, is not the one used for the fuel economy tests plotted on Fig. 3. The Zenith power curve, Fig. 1, on the other hand, is that obtained with the same jet, sleeve, and well as used for the economy tests shown on Fig. 4. When a slightly larger jet is substituted in the Zenith for that used during the economy tests, the power curve obtained coincided approximately with that obtained for the Marvel carburetter. *The two carburetters, therefore, give about the same power output when both adjusted for maximum power.* The speed of the maximum power is about 1,850 revs. per minute. At this speed the engine develops 60·9 h.p. The maximum torque is obtained at 1,100 revs. per minute. At this speed the brake M.E.P. is about 97lbs. sq. in. At the speed for maximum power output the brake M.E.P. is 79·5lbs. sq. in. The engine develops its maximum horse-power at a car speed of about 55 m.p.h., and maximum torque at about 32 m.p.h. when using the direct drive. The engine develops its A.L.A.M. or S.A.E. rating at 800 revs. per minute, with a piston speed of 667ft. per minute. At 1,000ft. per minute piston speed the power delivered is 47 b.h.p., or about 40 per cent. in excess of the rating.

Fuel.—The fuel used was an ordinary grade of commercial gasoline of density 65° Beaume. The higher calorific value as given by the Parr calorimeter was approximately 19,400 B.T.U. per pound. The lower calorific value is probably about 18,600 B.T.U., though this was not determined.

Fuel Economy Tests.—Tests were first made using the Marvel carburetter, with a maximum power setting. The fuel consumption averaged from 15 to 20 per cent. higher than the consumption in the tests plotted on Fig. 3, which were made after careful readjustment of the carburetter. In making this readjustment the aim was to secure a setting which would give good economy at all loads and speeds liable to be met with in actual service, and at the same time to ensure steady firing over the whole range. As a whole it is more nearly a maximum economy setting than a maximum power setting,

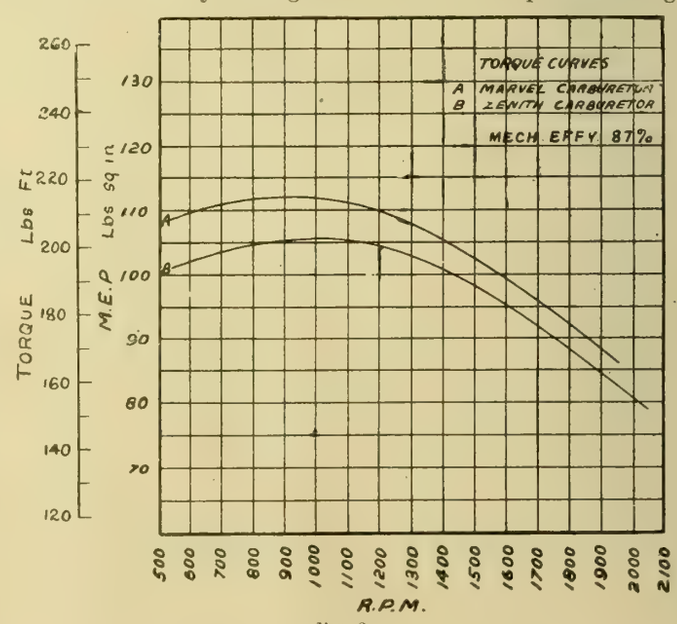


Fig. 2.

since at many points in the range of speeds and loads a further reduction in the consumption of 2 or 3 per cent. could be obtained in the laboratory without missing. The writer does not believe that a true maximum economy setting could be used in practice, however, because the mixture for maximum economy is so weak that missing would be bound to occur when atmospheric conditions varied slightly. Hence a practical setting for best all-round service should be intermediate

between a maximum power and maximum fuel economy setting. Reference to this point will be made later on in connection with the test plotted on Fig. 5.

The writer is satisfied that the results plotted on Figs. 3 and 4 are about the best that could be obtained using a single carburetter adjustment for all speeds and loads. Any further reduction of the fuel supply will cause missing to occur at some point in the range of speeds and loads employed. The settings used are indicated on the diagrams. A well, not

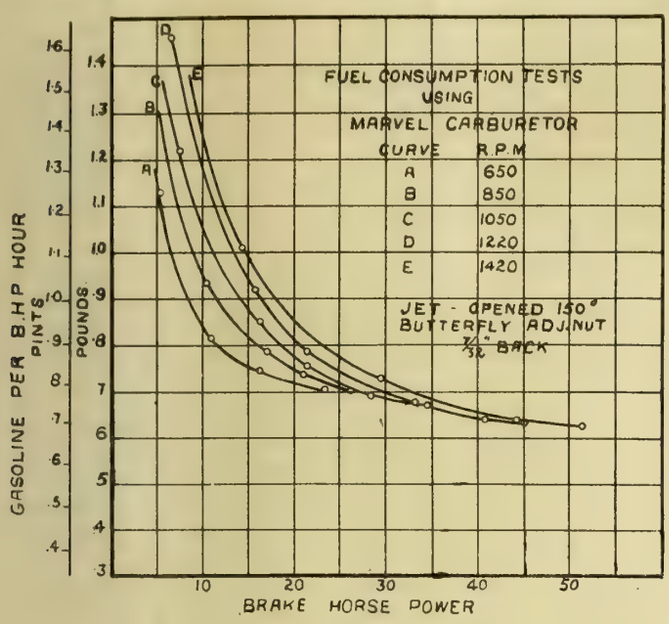


FIG. 3.

of standard size, was employed in the Zenith during the tests as noted on Fig. 4. The well orifice is not round, hence the diameter given, ·0035in., is only roughly correct. The construction of the Zenith carburetter is so well known as to require no explanation here. In the Marvel carburetter there are two adjustments provided, the gasoline needle valve or "low-speed" adjustment at the bottom of the carburetter and the air-valve tension screw for "high-speed" adjustment on the upper part of the carburetter. The high-speed nozzle, located below the air valve, is non-adjustable. The air around the engine had a temperature of from 80° to 90° Fah. Since the Zenith has no hot jacket it was probably working under a slight disadvantage as compared with the Marvel, which has the warming jacket, and therefore needs little hot air.

Comparing the curves of Figs. 3 and 4, the following points will be noted: (1) That below an output of 15 h.p. the two carburetters give about the same consumption. (2) That from 15 h.p. upwards the Zenith shows the higher economy. The difference in fuel consumption in favour of the Zenith is about 15 per cent. at 25 h.p. output, 10 per cent. at 35 h.p., 6 per cent. at 45 h.p., and 3 per cent. at 55 h.p. It will be seen, therefore, that the Zenith shows a decided superiority at the loads which are most used in actual service. As previously noted, the maximum power output is about the same when both carburetters are adjusted either for maximum power or best economy.

From the form of the curves in comparison with those obtained on similar tests made by reputable parties, the writer believes that the Zenith construction combined with proper adjustment gives a mixture of practically uniform strength over the whole range. The Marvel, on the other hand, when adjusted for best results at low and high powers, gave a stronger and less economical mixture at medium powers. It did not seem possible to remedy this by readjustment. This carburetter, as already noted, has only two adjustments. Closing the needle valve on the main jet improved the economy at medium powers, but caused the mixture to become too weak at small powers. On the other hand, reducing the tension on the butterfly valve spring gives more economical consumption at medium load, but weakened the mixture too much at small and full powers. This indicated that a stiffer spring was needed. Since these tests were made the writer is informed that the springs on the Marvel carburetters for this motor have been altered, and the McLaughlin Company claim that the economy has thereby been much improved.

In developing a given amount of power, this is always done most economically by using a low speed and heavy torque in preference to higher speed coupled with lighter torque. For example, referring to Fig. 4, when developing 25 h.p. at 625 revs. per minute, the fuel consumption is (Curve A) ·62lb. per brake horse-power hour. To develop the same power at 1,450 revs. per minute (Curve F) the consumption is ·73lb. per brake horse-power hour. This explains the higher fuel economy with a high ratio as compared with a low gear ratio.

In making the fuel economy tests, the tests were divided into several series, each series being run at speeds as nearly the same as possible. A curve is plotted for each series on Figs. 3 and 4. The speeds were chosen to cover the range liable to be used in practice as far as possible, though it was found impracticable to run at less than 600 revs. per minute on account of the difficulty of securing satisfactory operation of the brake at lower speeds. However, 600 revs. per minute correspond to only about 17 m.p.h. on the direct drive, and if the curve for lower speeds were needed it could be estimated pretty accurately from the form and position of the other curves. The usual curve given for the performance of auto engines is the "full-load" consumption curve, which is of little use in determining the carburetter economy, since the engine is very seldom used with wide-open throttle. The curves of Figs. 3 and 4 show the consumption for any power at any speed, and are therefore a much better criterion for the judgment of carburetter performance.

Automatic Spark Advance.—This engine is equipped with a Delco starting, lighting, and ignition system. The spark is advanced automatically by a centrifugal governor as the engine speed increases. A hand control is also provided for use under exceptional conditions. Maximum power, indicating correct spark timing, was always obtained with the spark lever full advanced except when running with maximum torque at low speeds. At full throttle and speeds up to 1,200 revs. per minute, the engine gave highest power with the spark lever retarded, the retard amounting to about 20° from position of full advance. For best results at full throttle this angle of retard decreases slightly as the speed increases, and became zero at about 1,800 revs. per minute. This may

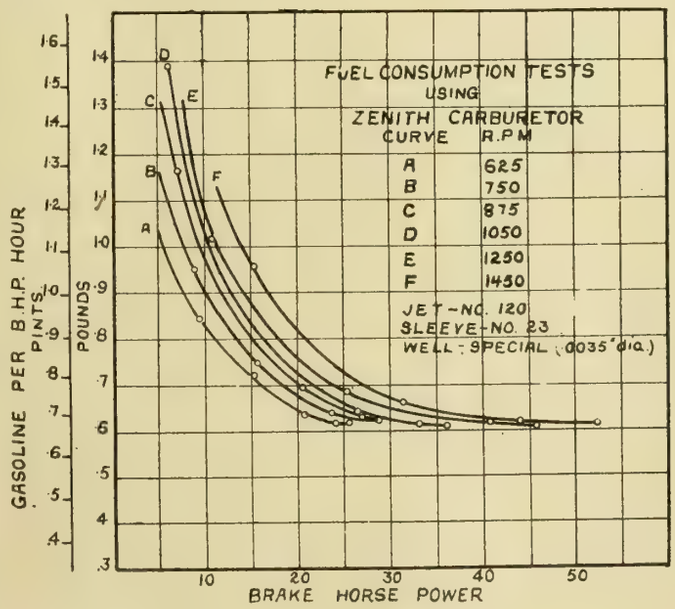


FIG. 4.

be explained by reference to the fact that at full torque the mixture is more dense, burns more quickly, and hence does not require to be ignited as early as when running with the engine throttled. Since the spark advance is governed entirely by the engine speed in this device, high and low torque conditions cannot be allowed for, and doubtless it would not be worth while to attempt to do so in any case. The conclusion arrived at was that the automatic control per-

forms its function very well and that the driver of the car would only need to use the hand control when going up a hill at low speed.

Gear Efficiency Tests.—Tests were made to determine the efficiency of the transmission. It was found that the brake would not produce enough torque to keep the engine speed down to a moderate value when driving through the low-speed gears, which have a reduction of 3·36 to 1. Consequently the tests were made only on the intermediate speed with a reduction of 1·504 to 1. The method employed was as follows: A test was made at a certain speed and load, using the direct drive. Without any change in the engine adjustments a test was run immediately after, maintaining the same engine speed and driving the brake through the intermediate-speed gears. The ratio of the horse-powers obtained at the brake in two tests is a measure of the gear efficiency. This is true under the assumption that the engine output in the two tests is the same—an assumption which is correct if proper care is taken to keep the working conditions constant.

A large number of pairs of tests made in this way at constant torque and varying speeds showed very consistent results. The gear efficiencies obtained varied from 95·5 to 97 per cent. when transmitting seven-eighths of the maximum torque, an extremely good result. Repeated tests showed no

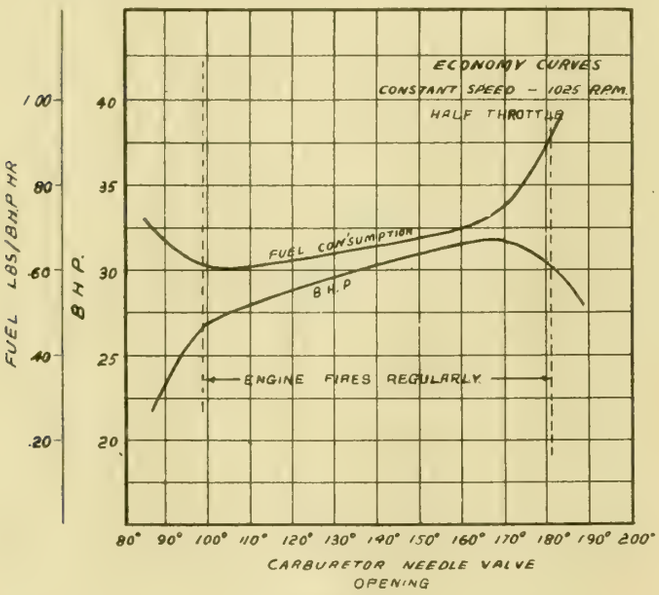


FIG. 5.

practical variation in the efficiencies. When in second speed the drive is transmitted through a pair of gears to a jack-shaft, and thence through another pair of gears to the driving shaft coupled to the brake. The results indicate that the loss in each pair of gears is of the order of 2 per cent. of the power transmitted. The total loss is about 1 h.p. The efficiency remained practically constant over the range of speeds covered, viz., from 700 to 1,350 revs. per minute.

Mechanical Efficiency Tests.—The method employed is that used by Clerk, Hopkinson, and others. Only three sets of tests were made, the first being at light load and low speed, the second at a moderate torque at medium speed, and the third with a nearly maximum torque at high speed. The results indicate that at full load the efficiency is over 85 per cent., decreasing to about 75 per cent. at quarter load. In making these tests it was noted that it made little difference which cylinder was short-circuited, showing that there was very little difference in the power production of the various cylinders. This would indicate that the inlet and exhaust manifold design is good, and that the compression ratio is uniform for all cylinders.

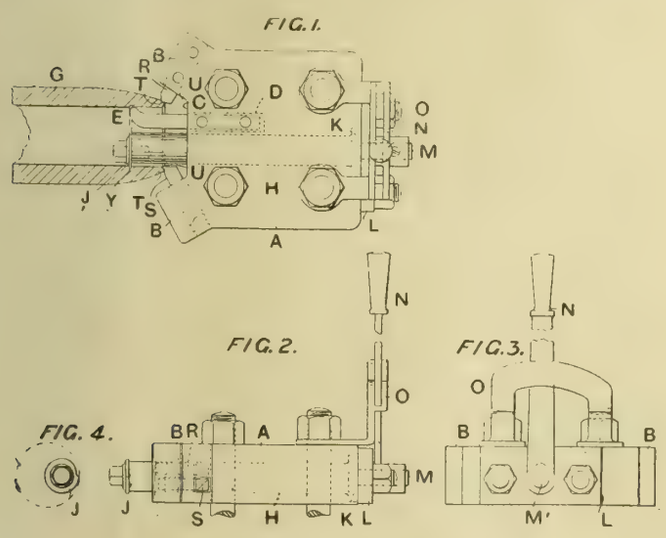
Tests to Determine the Effect on Fuel Economy caused by using Mixtures of various Strengths.—This series of tests was run at a constant speed of 1,025 revs. per minute and at half throttle opening, corresponding to about seven-eighths of maximum torque. The mixture was varied by altering the opening of the needle valve on the Marvel carburetter, a test being made for each position. The weakest mixture and the strongest mixtures used caused misfires, so that the tests cover the whole range over which the engine would run steadily. From these tests, the results of which are plotted on Fig. 5, the following facts may be deduced: (1) The highest fuel economy is obtained with the weakest mixture which will fire regularly. (2) That the mixture for maximum power is much stronger than that for maximum economy. (3) That the maximum economy setting (needle valve opened about 105°) the fuel consumption per brake horse-power is about 82 per cent. of that obtained with maximum horse-power setting. (4) That the maximum fuel economy setting gives a brake horse-power output of about 87 per cent. of that obtained with the maximum horse-power setting. (5) That the fuel supplied may be varied about 30 per cent. without causing the engine to miss.

The numerical values given would doubtless vary somewhat with the load and speed conditions. For example, at very light loads, with a mixture at lower pressure and temperature, the range over which regular firing would take place is doubtless narrower. Steady running is, therefore, a poor criterion for carburetter adjustment. To adjust the carburetter for maximum power means that the fuel consumption will be about 1·25 of that which would be obtained with a true maximum economy setting, and at least 1·15 times that which would be obtained with a practical setting, *i.e.*, one allowing a margin for cold weather, &c. But, as already pointed out, the acceleration would undoubtedly be less rapid with an economy setting, especially as nearly all carburetters have a tendency to give a weaker mixture for an instant after the throttle is opened. It is a well-known fact that the modern gasoline engine works at its maximum efficiency with a weak mixture. A stronger mixture, however, gives maximum power. Hence when a carburetter is adjusted by setting it so that the engine "runs best," the fuel consumption will be considerably higher than necessary. It would appear that a great many carburetters are adjusted in this way. This accounts for the improved economy which is obtained in many cases by the attachment of a spring-loaded check valve to the intake manifold, supplying additional air when the vacuum in the manifold reaches a moderate value. These valves are sold at fancy prices under various trade names, and while they no doubt do improve the economy when the carburetter was originally adjusted to supply a rich mixture, they produce results which could quite as well be obtained by readjustment of the carburetter itself.

Institution of Naval Architects: Admission of Students.—The Council of the Institution of Naval Architects is prepared to consider applications from persons desirous of joining the institution as students. Candidates must be between the ages of 18 and 25 at the time of election, and must be either apprentices, articled pupils, or students in naval architecture or marine engineering. The Council administers certain scholarships in naval architecture of the annual value of £100 (tenable for three years), which are offered annually for competition among students of the institution who are between 18 and 21 years of age. A post graduate scholarship in naval architecture, of the annual value of £200 a year and tenable for two years, is also offered annually by the Royal Commissioners of the Exhibition of 1851, and awarded on the recommendation of the Council of the institution. Candidates must be British subjects under 30 years of age, and must be nominated for the purpose by the Board of the university or college at which they have graduated. The Sir William White research scholarship in naval architecture, of the annual value of £100, has recently been established, and will be thrown open to competition after the conclusion of the war. A gold medal and a premium of books or instruments are offered annually for the best original communications contributed to the transactions of the institution by authors who are not members of Council. Full particulars of the above scholarships, and of the qualifications required for admission to the institution, may be obtained from the secretary, Institution of Naval Architects, 5, Adelphi Terrace, London, W.C.

TOOL-HOLDING DEVICE FOR LATHES.

MR. F. J. TAYLOR, "Oakwood," Briton Ferry, Glamorgan, has recently designed and patented the tool holding device shown in the accompanying cuts. The tool holder is of the kind which allows of accurately mounting a number of tools, each of which performs a different operation, some of the operations being brought about by a simple straight line feed of the tool head and others being brought about by turning a tool on the holder into operative position, as for example when the feed of the tool head has ceased. Fig. 1 is a plan of the tool holder fitted with four tools adapted to machine the nose of a projectile, a portion of the latter being shown in section. Fig. 2 is a side elevation of Fig. 1; Fig. 3 is an end elevation of Fig. 2; and Fig. 4 is an end elevation of the disc tool seen in Fig. 2. The holder which is adapted for use in an ordinary engine lathe or for placing on flat turrets consists of a thick plate A having projections B formed at an angle somewhat greater than 90° to the side C lying between these two corners. A slot D is provided for the reception of the shank of a tool E, the end of which is bent round so as to bring the cutting edge into position for counter-boring or cutting a cylindrical surface when the holder is fed in the direction of the axis of



TOOL-HOLDING DEVICE FOR LATHES.

the work G. A bar H of circular cross section is passed through a hole in the plate A, and its front end has mounted upon it a cutter J, which can be turned into, or out of, cutting position by giving a partial turn to the bar H in one direction or the other. This will be readily understood from Fig. 4 in which the tool J is seen in cutting position. A collar K is formed on the bar H near its rear end and this collar bears against the rear end of the holder A, the bar H being held in position by a bracket L bolted to the rear end of the holder so as to press against the rear face of the collar K, the bracket having an aperture for the rear end of the bar to pass through. The rear extremity of the bar H is provided with a handle N by means of which the bar may be turned. A guide and stop device O is bolted to the holder for guiding the lever N and limiting the amount of turning movement imparted thereto. Each of the projections B is formed with a slot and provided with means for holding a tool therein, the tools R, S when mounted being directed inwardly towards the centre line and forwardly at a convenient angle. The tool R in the horn B has its cutting edge suitably formed and arranged for producing the lip or shoulder T, and the tool S has its cutting edge suitably formed and arranged for producing the chamfer seating U. The holder A in an engine or flat turret lathe is mounted upon a suitable slide rest, flat turret, or other feeding device, so that its centre line coincides with the axis of the work G in the chuck.

THE INSTITUTION OF CIVIL ENGINEERS.

PRESIDENTIAL ADDRESS.*

(*Concluded from page 408.*)

ALL young engineers should take every opportunity of carrying out experimental work. Such opportunities occur on nearly every undertaking. It need not be original work, as that is not always possible, but even the repetition of work previously done gets one interested and accustomed to that class of work, and it may be the means of correcting and enlarging the work done by others. The great help in this kind of work is the cultivation of observation. Indeed, if our eyes are open we may often see experimental investigation being carried out, often in the streets, especially in and near large cities like London.

I mentioned in this institution, some time ago, that I hoped, when the finances of the institution had recovered from the effect of the large expenditure on our new building, consideration might be given to setting aside an annual amount for certain experimental work. We have in the past subscribed largely to experimental work at the National Physical Laboratory, and to work undertaken by committees of members of the institution, but the idea I had was on rather different lines. Very frequently the engineer in charge of works or shops sees opportunity for carrying out experimental work with very little money expenditure, but frequently that small amount of money cannot be found. If there were a fund available from which grants could be made in such cases for certain definite experimental work, I consider it would be very valuable, both to the members as a body and to the member carrying out the investigation. In the latter case the member would discover that he got more real knowledge by carrying out a small piece of experimental work himself than if he had read about 10 times the amount of work carried out by other persons.

A quality which an engineer's work frequently develops is that of organisation, and this, if cultivated, frequently leads to very high positions. We have seen in this country, and also in America and the East, engineers who possess the faculty of organisation in control of some of the largest railway systems. No large enterprise can be carried out successfully without capable organisation. Engineers who have, or who develop, this quality may often, although not endowed with exceptional engineering ability, attain to positions not open to those who are devoted to engineering work solely. I think I am hardly wrong in saying that our most successful contractors owe their success in great measure to their organising capacity, and engineers with the same quality are indispensable to them.

I think I have said enough to show young engineers that success depends on many matters besides knowledge of engineering, and that even with a moderate knowledge of it other qualities may be developed which command a high money value and are the means of attaining to important positions.

There now comes probably the most difficult question of all for a young engineer, the chance which makes him known, the opportunity by which he can show that his qualities have been undervalued. There are many curious ways in which this opportunity arises. He may work steadily for many years, and it may suddenly come in the most unexpected way, and it generally does come once if deserved. I read a short time ago in a Canadian engineering journal an article headed, "What is Luck?" and I quote the following from it: "You often hear it said, 'That fellow is certainly lucky.' As a rule the luck in his case consists in getting up at six in the morning, living on half what he earns or less, meeting his appointments, minding his own business, working like Sam Hill, and always keeping an eye on the track ahead. There may be exceptions, but this is the general rule." I do not think this quotation is a good definition of luck, but it is a very good one of the road along which luck is generally found travelling.

I am not, however, going further into this question tonight, except to point out that I am not at all sure that young engineers realise the importance of attending the meetings, joining in the discussions, and contributing papers to this and other institutions. I don't think I have ever written a paper,

* Delivered by Sir Maurice Fitzmaurice, C.M.G., M.A., M.A.I., LL.D., November 7th, 1916.

or got out notes for a discussion, without discovering that there were several points on which my information was deficient in some particular, which otherwise I should not have known it was necessary to look further into. It is extremely difficult in many cases for even a very good young engineer to get himself known, and the reading of papers and joining in discussions is almost the only legitimate form of advertisement open to him. I can bring to mind, in my own experience, two cases where speaking at this institution was the means of obtaining two excellent appointments. I happened to be particularly impressed by the practical remarks made here by two young engineers whom I had not known or heard of before. Very shortly afterwards I was asked to suggest men for two good posts, and, after I had made a little enquiry, I recommended these two men. They fully justified their selection, and I think are now on their way to high places in the profession.

I began this portion of my remarks with the idea of speaking on the want of success in individuals, but in some way I seem to have veered round to speaking of a few of the ways to success. It is better that it should be so; it is a much more pleasant subject.

I take the opportunity of saying a few words with reference to the difficulties which have arisen between employers and employed in recent years, as being matters which have a good deal to do with the success or otherwise of engineering works. During the period of the war it has been extremely satisfactory to find that many of these troubles have been shelved for the time being. The temporary truce has, however, in some cases not been carried out so far as one would wish and expect, bearing in mind the serious struggle in which we are engaged, and considering that everyone should bear some share of the loss and discomfort which war entails. We can, however, never forget the great part played by labour and labour leaders in this war, and we must remember that nearly all labour troubles which have arisen have been in direct opposition to the wish and advice of the trade union officials.

It is, however, with reference to the relations between employer and employed during times of peace with which I am most concerned to-night. We had at this institution, towards the end of last session, a most interesting and brilliant lecture which dealt, among other things, rather fully with some labour questions. I did not agree with all the propositions then laid down, but many of them were such as to invite serious consideration.

I had for many years the direct control of a large body of working men, and have had opportunities of inside knowledge with reference to many labour disputes with which I had no direct connection. The two points which struck me as fundamental in nearly every case were that the employer should pay a good living wage, and that the employed should do a good honest day's work, or perhaps I should say in some cases an honest week's work. The so-called "restriction of output" policy which some trades indulge in seems to be the first step in a most vicious circle. It certainly does not lead the employer to look favourably on proposals for increase of wages. It must be extremely irritating for him to know that the output per man could be easily increased in some cases, without undue exertion, and that under such conditions he could cheerfully concede an increase in wages. This policy is not confined to our own islands only.

I had an opportunity, some time ago, of discussing the question with one who had full knowledge of labour conditions in a certain State, and he informed me that, during 10 years, wages in his area had gone up 40 per cent. and the output per man had gone down 30 per cent. The general conditions no doubt justified the increase of wages, but there seemed to be no reason for the diminution of output.

We all wish to see labour contented. In Burke's speech in 1775 on conciliation with America, he said, "The question with me is not whether you have a right to render your people miserable, but whether it is not your interest to make them happy." I think that expresses our view with regard to labour to-day.

It is impossible to expect a high standard of duty to exist at all times among workmen unless they can live under such conditions as will allow them a chance of bringing up their families decently and making some adequate provision for old age. I am quite aware of the advantages as regards free education, medical attendance, out-of-work benefits, old-age pensions, and sometimes free meals for children, which exist; but better wages than those existing before the war, with a greater feeling of responsibility by the individual would, in my opinion, be much better than all these free advantages, with the exception of that of education. Organised labour has great powers and correspondingly great obligations, and it ought to be in a position to begin these obligations at home. If obligations and responsibilities do not exist in the elementary matters there is very little chance of their real existence when large questions have to be solved.

It is often difficult for the mass of labour to understand the cost of finding large sums of money to finance great industries, and that such money has to be paid for out of profits. It is difficult for labour to realise the risk which capitalists have to take, and the fact that in many works large sums are spent on research work which may only give a return after a long period, or may in many cases appear to give no return, if it be considered that negative results have no value, which is far from being the case. It is also sometimes difficult for labour to understand that the work and organisation of one man may in some undertakings mean a difference in profits of hundreds of thousands of pounds, or the difference between success and failure, and that such men and their immediate assistants deserve and earn the large sums they receive. It is on these accounts that labour often considers that it does not get a fair share of the profits. I do not mean to say the profits are always fairly divided, and it would be difficult to say what a fair division should be.

I also do not believe the working man has any idea how the prosperity of this country, and with it his own prosperity, depends on our export trade, or how our manufacturers have had to meet the fiercest and sometimes unfair competition of other nations, not only in foreign countries but in our overseas Dominions. There is, however, nothing surprising in this want of knowledge when we remember that very few of us realised a few years ago how Great Britain was exploited by German competition, frequently underhand and unfair, with the object of capturing our vital industries and getting control of a great deal of our finance and trade. We have, however, learned a great deal in the last two years, and I think many working men are not above taking interest in such questions.

How is it possible permanently to raise the wages of the working man beyond those existing before the war? Is it reasonable to expect that a greatly increased output per man can be obtained without undue exertion? We all know it is possible. It means that employers must provide the best modern machinery and that men and trade unions must give up the idea of restricting output. It means that capital has to obtain such a measure of the confidence of labour as is necessary to convert men and trade-union officials to the view that increased efficiency will be to their great advantage and give increased comfort and health. This can only be done when it can be shown that under such conditions there will be plenty of work to go round for all, and it means that our trade has to be increased.

This leads at once to the question of the national campaign for maintaining and increasing our trade, but this is outside the scope of my address. I do not mean to say that this institution is not a place to discuss questions of industrial and commercial policy. On the contrary, I think it would be well if we gave more consideration to such subjects, and many of our members are well fitted for dealing with such questions. I may, however, say that it is a source of much satisfaction to know that great efforts are being made by the British engineering industry and the Government to be ready when the time comes. I hope the Government will not be above taking the advice given by those who are fully conversant with all the aspects of international trade competition. I consider one of the most hopeful and important events which has occurred recently in connection with our trade is the speech of the Prime Minister in the House of Commons on August 2nd last, when dealing with the White Paper on the proceedings of the Economic Conference of the Allies, held in Paris in June of this year. Mr. Asquith gave, in the begin-

ning of his speech, the two main objects of the Conference. "One was to convince the enemy that the Allies, whatever their individual points of view may be on economic matters, are resolved to wage this war with as complete unity and determination in the economic as in the military sphere. The second object was to make such preparation for the period following on a declaration of peace as seemed essential to the Allies in view of the known attitude and will of Germany."

He drew special attention to the extraordinary enterprise and resourcefulness shown by a large number of British industries since the war broke out, and laid particular emphasis on two tendencies. "The first is the development of trade associations for common action at home and abroad raising the average standard of production. The second is the recognition of the leeway which we have to make up as regards scientific research and the utilisation of its results and its application to technical and industrial purposes."

He concluded his speech by saying: "No one who has any imagination can possibly be blind to the fact that this war, with all the enormous unheaval of political, social, and industrial conditions which it involves, must in many ways, and ought to if we are a rational and practical people, suggest to us new problems or possibly modifications in the solution of the old ones. I would regard it as deliberate blindness to the teachings of experience if you were to say we had forgotten nothing and had learned nothing from a war like this. I trust and believe we shall be able . . . to work out a policy of common action which will make the peace which is to come at the end of this war a lasting peace and a peace which will redound not only to the credit of our arms but to the stability of our industry and finance."

I make no apology for quoting at some length from the Prime Minister's speech, because it can only mean that the whole power of the Government will be placed at the disposal of our trade; that, as Mr. Asquith stated, steps will be taken to ensure protection against dumping and other unfair competition, and that we shall never again be dependent on enemy countries as regards essential industries. It means that Australia and Canada, whose representatives attended the Paris Conference and approved its resolutions, together with our other Dominions beyond the seas, have set their seal to a united Empire for purposes of peace as well as for war.

However important the Prime Minister's declarations, and however necessary the help of Government, I attach still greater weight to the spirit which is at present animating our commercial leaders. The thorough-going determination of our manufacturers to organise British industries for more efficient production, and the steps being taken for pushing our trade outside these islands, are certainly on a different scale from anything previously attempted. The first part of the work to be carried out is put so clearly and shortly by the president of the Federation of British Industries that I quote his words. The objects of the association "may be summed up briefly as the organisation and development of industry now and after the war in co-operation with labour and in conjunction with the Government and Government Departments."

I hope those who are dealing with the development of our foreign trade will not fail to include among other matters full consideration of the important question of the adoption of the metric system of weights and measures in this country. This system is obligatory in 34 countries, with a population of 437,000,000. In an official report issued by the Government of the United States this year I find the following statement: "Commerce, technology, and science have, on account of their international character, availed themselves of the advantages of the metric system more than manufacturing, which is local, and, unlike exporting, not in direct touch with world markets. Hence, science and commerce, with their world-wide outlook, should be the advisers of industry, and their conclusion is that the first principle is to supply what the customer needs, and that international business requires international weights and measures." The British Chamber of Commerce at Buenos Ayres in February, 1916, passed the following resolution: "That this Chamber unanimously recommends to the immediate attention of the British authorities the capital necessity of the adoption of the metric system as a very material factor to assist the expansion of Britain's overseas trade after the war."

Is there any reason why we should not be successful in our trade campaign after the war? Over two years ago we entered a war, not of our making, and for which we were not prepared. Under the late Lord Kitchener, an honorary member of this institution, an army of over 4,000,000 men was organised; under Mr. Lloyd George was organised the manufacture of munitions on a huge scale. Canada, Australia, New Zealand, India, South Africa, and the other members of our overseas Empire came to our aid in such numbers as we could never have anticipated. Burke rightly gauged human nature when he wrote: "War is a situation which sets in its full light the value of the hearts of a people."

It is pleasant at times to take an optimistic view, and such views sometimes come true. In a remarkable series of lectures on England and Germany by the late J. A. Cramb, delivered in 1913, a year before war was thought of, he discussed the supposed decay of our Empire, and in the last lecture said: "Even now, in 1913, when I consider England and this vast and complex fabric of Empire which she has slowly reared, its colonies, its dependencies, the cosmic energy which everywhere seems to animate the mass in its united life and in the separate States or principalities, all such comparisons with decaying empires appear an irrelevance or a futility. Whatever be England's fate, it will not be the fate of Venice or Byzantium. And as a proof of the validity of this impression, or this conviction, I seem to discover everywhere stirrings as of a new life, to hear the tramp of armies fired by a newer chivalry than that of Crecy, and on the horizon to discern the outline of fleets manned by as heroic a resolve as were those of Nelson or Rodney." It is a matter of regret that the author did not live to see his anticipations realised.

We cannot engage in a war where men of all classes are fighting shoulder to shoulder without some diminution of the old class prejudices. We cannot fight side by side with our overseas brothers without getting to know each other better, and without realising that we all have to continue after the war to do our best for the Empire with as little internal friction as possible. With such better knowledge of each other, and remembering that unprepared we entered a war in which we are, with our Allies, achieving success, is there any reason why, when fully prepared and in full agreement with our Allies and our overseas Empire, we should not be successful in peace?

Of course I am an optimist, but not one who imagines that what we want can be obtained without fighting and working for it. It may only be the dream of an optimist to imagine that this country can be run for the benefit of our own people, without preconceived views, without ancient shibboleths, without red tape. It may be a dream, but it ought to be a fact.

I am afraid I have gone somewhat beyond the lines I laid down for this address, and my only excuse is that the conditions under which we are living are exceptional, and that it is difficult to keep daily thoughts out of anything we may write or say.

Gentlemen, the greater portion of my address to you tonight may possibly be considered too much out of the common because it deals with some of the very common matters which have to be considered by engineers. My remarks are really reflections on the different events which have occurred during my own life as an engineer, extending now to over 30 years. I hope they at least show that there is still ample room for investigation and experimental work, which may enable us to give still greater value to our clients, and that it may influence young engineers especially to devote some of their time to that class of work whenever opportunity for doing so is present.

THE RECLAMATION OF WASTE FOUNDRY SAND.*

BY H. M. LANE.

IN the past 20 years many attempts have been made to reclaim foundry sand. The principles covered in these experiments varied greatly, and the ultimate object sought also varied greatly. A process that is successful with steel-foundry

* Paper read before the Cleveland meeting of the American Foundrymen's Association, September, 1916.

sand might fail utterly with brass-foundry or aluminium-foundry sand, owing to radical differences in characteristics of different materials. Steel-foundry sand should be made up from pure silica sand, the grains of which are rounded rather than angular. This sand should then be bonded with a sufficient amount of refractory fireclay, so that it will hold its shape when rammed into the mould. All sand is damp, or as it is termed "green," when rammed in the mould. The bond must remain active whether the mould is poured when in the green state or is baked or skin dried. The percentage of fireclay used in such a mix is relatively small, and the so-called wearing out of the sand is due mainly to the stopping of the fine passages by small grains, resulting in the breaking up of the larger grains under heat, and from dry or burned bond material.

Another interesting fact is that the mass law of chemistry influences very largely the temperature at which a given size of grains will start to melt or burn into the castings. Very fine sand will burn into a steel casting several degrees lower than coarse sand, and hence in this type of work we encounter the necessity of freeing the sand from these small and particularly angular grains. For such work a cleaning process that will remove the burnt clay and the fine sand dust is what is necessary. This may be accomplished by washing or dry cleaning.

For dry cleaning a number of systems have been devised, and some patents taken out. One system that has been used in the west treats the sand with high-pressure air in such a way as to cause the grains to impinge one upon another, giving a sand-blast action, which cuts off any adhering clay, scouring the grains. The system is then arranged to take away the fine dust and leave relatively clear grains. Other systems simply pass the sand through an apparatus which exhausts the finer dust without any attempt to give the sand a thorough scouring.

In this commercial world of ours, the process which will produce a product just good enough for us to use, at the lowest cost, is the one that will ultimately be used, even if other systems may give a better though more expensive product. In steel-foundry practice the ultimate factor is the cost of a ton of finished castings, and a process which recovers, let us say, 80 per cent. of the sand in a fairly usable condition may be better than the one which recovers 90 per cent. in a better condition but at a higher cost.

When we jump to the opposite extreme and try to clean or reclaim the exceedingly fine brass or aluminium moulding sand we encounter a much more serious problem, and one which hardly is worth while attempting. It is, however, advantageous to clean the core sand. The statements thus far made have been with reference to moulding sand. In steel-foundry practice the core sand used is very similar to the moulding sand, and can always be cleaned to advantage. In the experiments which were made it was evident that at least 80 per cent. of all waste sand material shipped out of the ordinary foundry can be recovered for re-use in some form. In the case of heavy grey iron work it can be dry cleaned, rebonded with proper kind of clay, and used as heavy work moulding sand. In the case of aluminium and brass work the general run of sand from the foundry can be cleaned and used in core work with resin or water soluble binders. It, however, does not work well with oil. For the thorough cleaning of certain classes of sand, the wet process seems to be the best, but this necessitates first a scrubbing and then a washing, and takes quite a complicated plant, though the actual cost of cleaning per ton is low.

The foundryman is not interested in ultra or scientific processes, but is interested in the production of castings at a reasonable cost, and to accomplish this the simplest sand-cleaning method available is what he wants. In some cases passing the sand over a series of sieves which will first take out the coarse waste material, and which will next remove the fine or dust material, has been found to give a good product for rebonding for use in foundry work for a considerable line of grey iron castings. Each case, however, must be studied on its own merits, and local influences caused by the different grades of core and moulding sand used have an important bearing on the subject.

SPRINGS.*

BY C. E. ISQUIRE.

(*Concluded from page 417.*)

Characteristics of Spring Steel.—The following table shows the properties of the spring steel generally used for railway work. The figures are not for any particular test-piece, but are the average of some hundreds of tests of steel by several different makers.

Characteristics of Spring Steel.

	Laminated springs.		Coil springs.	
Analysis—				
Carbon	·60	·45	1·0	·8
Silicon	·08	·10	·05	·09
Sulphur	·029	·050	·029	·050
Phosphorus	·031	·051	·031	·051
Manganese	·63	·87	·60	·8
	As rolled.	Hardening and tempering.	As rolled.	Hardening and tempering.
Tensile test—				
Max. stress, tons per sq. inch	46	81	59	—
Elastic limit, tons per sq. inch	30	75	—	—
Elongation, per cent. in 8in.	17	4	9	—
Reduction of area, per cent.	42	12	14	—
Modulus E.	—	13,500 tons per square inch.		
Torsion Test—				
Max. shear stress, tons per sq. inch	—	—	—	70
Elastic limit, tons per sq. inch	—	—	—	43
Modulus N.	—	5,000 tons per square inch.		

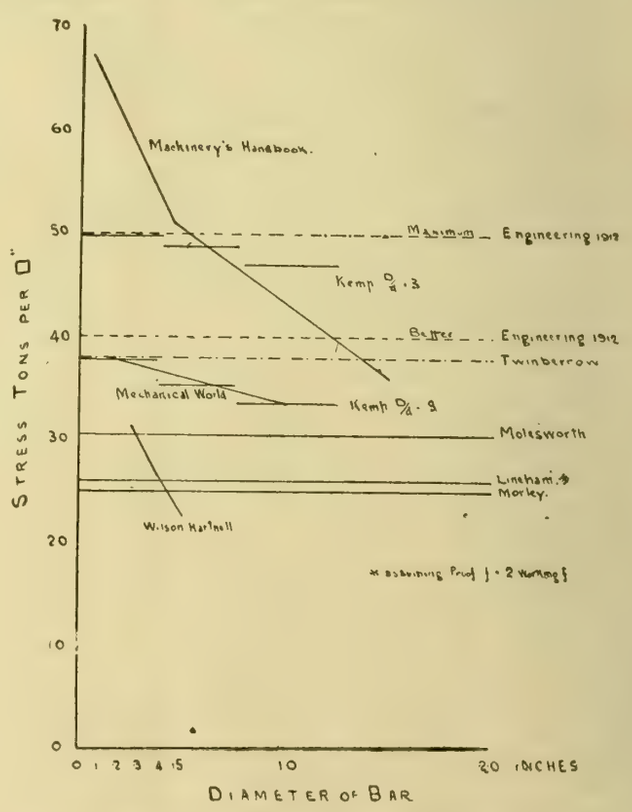


FIG. 3.—PROOF STRESS IN HELICAL SPRINGS OF CIRCULAR SECTION.

The two analyses show steels that correspond with the two British Standard Specifications. There is not much difference between the physical properties of the two grades, but springs made from the purer material should have a longer life. You will notice the difference in strength that hardening and tempering makes. It is the ultimate tensile or sheer stress for

* Paper read before the Junior Institution of Engineers, November 20th, 1916.

laminated and coil springs respectively that limits the range and load, and it is the modulus that governs the ratio between them. Contrary to general ideas, the modulus is practically the same for all qualities of spring steel, and whether soft, hard, or tempered

The figures to which the author wishes to call attention are the elastic and breaking limits in tension for laminated springs and in shear for coil springs. When speaking of stress in coil springs it is always the shear stress that is referred to. By proof stress is meant the maximum fibre stress to which the material will be subjected when under the scragging test, and this should be in excess of anything the spring will be subject to in service. The working stress will then be something less, say from one-third to two-thirds, depending on the purpose of the spring.

Unwin gives three as a factor of safety for material subject to static loads; five when subject to fluctuating stresses; and 12 when subject to shock. Taking five as the lowest we can use for such purposes as springs, and assuming that it refers to the working stress, the working stress for coil springs would be 14 tons per square inch and the proof stress about 28 tons per square inch, or in very exceptional cases it might be as high as 42 tons per square inch.

In practice the stresses are much higher, and there is a variety of opinion as to what really is the maximum safe stress. The author has endeavoured to show the figures given by the various authorities in Fig. 3. In that chart it will be noticed that some authorities adopt a uniform stress for all sizes of bars, while others decrease the stress for the larger bars. The author thinks the latter is correct, and for this reason. Hardening very much alters the strength of the steel, and depending as it does on the rate of cooling, a difference of seconds in hardening makes a great difference in the strength of the material. It is obvious that a large bar will not cool so quickly as a small one, and, what is of more importance, will not cool so uniformly. So the final material is not homogeneous, and has a less average strength.

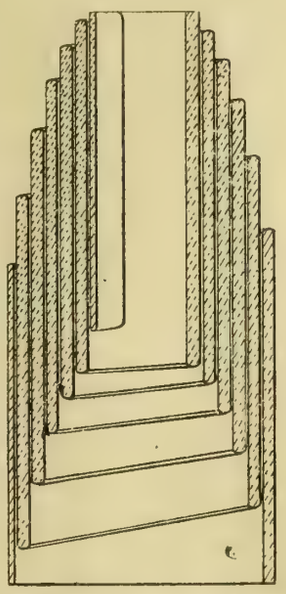


FIG. 4.—SECTION OF VOLUTE SPRING SHOWING HOW COILS SHIELD ONE ANOTHER IN HARDENING.

Stresses.—This difference in rate of cooling is most marked in the case of volute springs, and if you examine Fig. 4 you will see that the inner coils are almost completely shielded from the hardening medium, and in practice the author finds that for satisfactory working a volute spring should always have a lower stress than a similar helical spring due to this cause. Actually the stress is generally in the neighbourhood of 50 tons per square inch, but one is often asked for springs in which the stress works out to 60 or 65 tons per square inch, and a few weeks ago an enquiry was received for a spring in which the stress would have been 140 tons per square inch.

The author has collected together a number of designs that have failed. Large numbers of the springs were in use, and the substitution of amended designs involved great inconvenience and expense in alteration to rolling stock. The average proof stress in these works out at 73 tons per square inch, so that we may be quite sure that the safe limit is below this. There is some explanation and excuse for these high stresses, but it is false economy, and, speaking generally, there is no engineering structure which has such a low factor of safety, and there are few in which the design receives so little attention at the hands of engineers. The stresses are worked out in much the same way as for a beam or a shaft, but all the theory of design is based on the assumption that the elastic limit is not exceeded, and yet the very first thing the spring maker does to the completed spring is to give it a very considerable permanent set, *i.e.*, he exceeds the elastic limit.

In a bar subject to bending or torsion the stress is not evenly distributed and is zero at the neutral axis, so that all the fibres do not reach the maximum stress at the same time. When some of them reach the limit, set takes place accompanied by a new distribution of stress, so that a larger number of fibres are now subject to maximum stress. So far as the author is aware, it is quite impossible to calculate this new actual stress with certainty, and it would seem that the theory and formulæ, &c., resulting from it are worthless, but this is not so. One can calculate the dimensions, loads, and deflections with a greater degree of accuracy than one can make the spring. When a material is stressed slightly beyond its elastic limit, a new and higher limit is formed, as in wire drawing, and the same thing occurs with springs, in a way, one might say, that one then starts afresh. In calculating the stress we use the deflection of the finished spring only, and not the total initial deflection, and in spite of the theory being more or less incomplete, the stresses obtained really do approximately represent the actual ones, and in any case do so relatively.

Energy Diagram.—The results of the deflection tests can be plotted to scale, and Fig. 5 shows results of a test of the buffing spring in an English goods wagon. In a laminated or volute spring there is a certain amount of internal friction, due to the relative movement of the plates. This makes the total deflection less for an increasing load than for a decreasing load, *i.e.*, the increasing load is represented by the upper line and decreasing loads by the lower one. Under a given load, say five tons, the camber of the spring may be anything from 3in to 4½in. The dotted centre line represents the true restoring force of the spring. It will be remembered that the definition of a spring is "a contrivance for storing energy." Just as an indicator diagram represents the energy given out by the steam in one stroke of the piston, so the area of this diagram represents to scale the

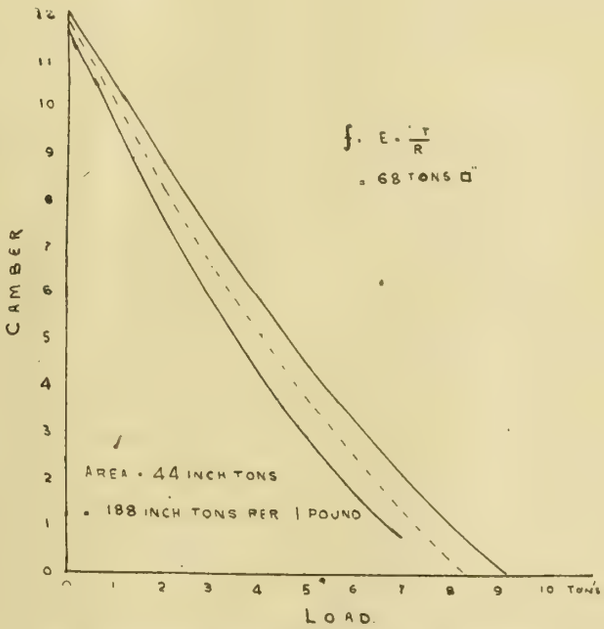


FIG. 5.—STANDARD BUFFING SPRING, 5ft. 10½in. long straight, 14 plates 3in. × ½in., weight 234lbs.

amount of energy stored in the spring, and in this case is 44in. tons. To make comparisons between springs one wants to bring the results to a common denominator, and to do this one finds out the work stored per unit of spring. The units used by the author are inch tons of work per pound of spring, and this is the "resilience" of the spring. The term resilience is often used in a very loose sort of way, but it has a definite meaning. It is the amount of work that can be stored per unit volume, and in the case of springs the resilience is the direct measure of the efficiency of the spring.

The diagram in Fig. 6 has been made from the test of the volute spring shown in Fig. 4, and it will be noted the resilience has gone up to 22in. tons per pound, although the stress is lower. Here again, one may see the effect of friction. The buffing and draw gear in existing stock tends to become too light for the increasing power of locomotives and weight of trains. In consequence, engineers often ask for stronger

springs, and, naturally, judge the strength of a spring by the maximum load it will carry. It should, however, be borne in mind that a high ultimate load is not the only point to strive for. The value of a spring in minimising shock depends directly upon its power to store energy. It is seldom possible to use a spring large enough to take up the whole energy of a moving vehicle, and the balance is expended in shock. It will be seen from the diagram that although the spring carries an ultimate load of a little over 8 tons, yet, after 6½ tons, stores very little energy, and that the total resilience and maximum stress demand equal consideration along with the ultimate load.

Fig. 7 shows the deflection diagram of a helical spring and depicts the great advantage of the circular section. Although

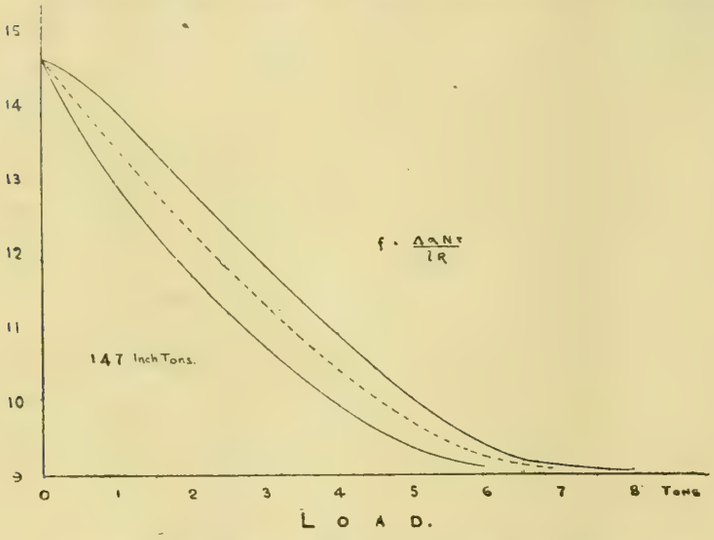


FIG. 6.—VOLUTE SPRING. 14¼in. × 6¾in. × 2¼in.; 9in. × 5/16in.; weight, 66¼lbs.; stress, 55 tons per sq. in.; resilience, ·22 inch-tons per lb.

the stress has been reduced to 48 tons per square inch, *i.e.*, less than either of the other two, the resilience is ·323in. tons lbs., *i.e.*, nearly twice that of the laminated spring, and 62 per cent. higher than the volute. Other sections will show different results, but the helical spring, of plain circular section, has easily the highest efficiency. Calling this 100 per cent. efficiency, some of the volute sections come out next at about 62 per cent., and the square section at 60 per cent., and all other sections have a lower efficiency still.

Limits in Manufacturing.—There is no need for the author to urge the importance of fixing limits in manufacturing. The use of limit gauges is well known, and their advantages obvious. In considering railway springs, however, it should

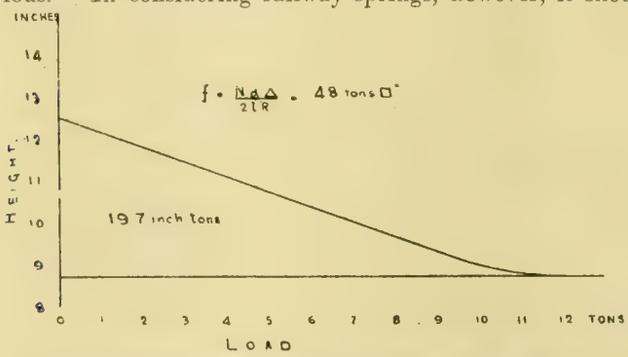


FIG. 7.—HELICAL SPRING. 12½in. × 7¾in. × 4⅛in.; 1 17/32in. diam.; weight, 61lbs.; deflection, ·357in. per ton; resilience, ·323 inch-tons per lb.

be remembered that it is a black job, and the limits should be those suitable for smiths' work and not those for the machine shop. Engineers are sometimes a little unreasonable on this point.

A spring is, of its very nature, flexible, and it is impossible to get the same degree of accuracy as with a rigid body. If left unloaded, it will recover part of its initial set, especially if subjected to shocks, such as it will get in transit from the makers' works. A coil spring also increases in diameter when compressed, and clearances should allow for this. The common clause in specifications limiting the total variation in length to ⅛in. for all kinds of springs, is not practicable. The manufacturer can often work well inside this, but there are cases when he would have trouble, even if given three times the amount.

Generally speaking, spring makers have now reached the greatest accuracy at present commercially possible, and it is the rolling mill which fixes the limit. If the dimensions of springs bars are within 2 per cent., it is good average rolling. In this the author is not speaking of odd samples, but hard and fast limits within which one can guarantee to work month after month. What is a fair tolerance for springs? While it is not possible to give a figure that will apply in every single instance, a total variation on any dimension of 3 per cent. covers most cases, and is a reasonable figure for good average work.

Earlier in the paper the author mentioned the clause relating to scragging strokes in the British Standard Specification No. 24, for laminated springs. This clause limits the amount of deflection, and consequently the stress, and has had a very good influence on the design and tests of laminated springs. Nothing of the kind is specified for coil springs, and springs are regularly made to inferior designs in which the stress is excessive, and subjected to tests that materially reduce their life.

Proposed Standard "Scragging" Clause for Coil Springs. The natural question is, cannot a clause be devised to effect the same end as that for the laminated springs? In the author's opinion it can, and he would suggest the following as a basis for discussion. In place of existing clause 4, Specification 7 and 7a, which is never fully carried out, substitute: "Each spring shall be tested by being deflected smartly twice by a steam scragg. The amount of deflection should not exceed $\frac{W \times K}{L}$ where W is the weight of the spring in lbs., less the weight of one coil. L is the maximum load in tons corresponding to the deflection, and K = 1·1 for compression springs made of circular section, and ·6 for all other sections. They must then, if required, stand being deflected again three times in quick succession without showing any permanent set. Springs shall also be tested under varying loads to determine the range and deflection per ton."

This clause would limit the proof stress to about 58 tons per square inch. It has been simplified as much as possible and consequently is not absolutely accurate, but it is sufficiently so for the purpose. It is not suggested that 58 tons per square inch is the ideal figure for the maximum proof stress, but is probably the lowest that would have any possibility of general acceptance in view of many existing standard designs.

CHIMNEY AND MECHANICAL DRAUGHT.

IN the course of a paper read before the recent annual convention of the American Smoke Prevention Association, Mr. E. R. Fish stated that boiler and furnace practice had changed to such an extent within the last few years that the generally accepted ideas of a few years ago were now largely obsolete. Most large and many small plants were now equipped with mechanical stokers of some one of the numerous types, particularly in those centres where room was limited and smoke abatement laws were enforced. While chimneys alone were still largely depended upon to produce the draught necessary for the combustion of fuel, the tendency was strongly towards supplementing them with mechanical equipment. The effective draught, or that which was used for getting the air through the fuel bed, might be produced in three general ways: First, by the natural draught of the simple chimney; second, by induced draught; third, by forced draught. But when the whole of the boiler installation was considered, several combinations of these might be desirable or necessary.

Where natural draught alone was depended upon, it must be of sufficient intensity to overcome all the resistances from the top of the stack to the ashpit door. With a given height of stack the available draught was practically fixed, although it varied with the temperature, state of the weather, barometer, &c. A chimney of moderate height could not supply a sufficient draught to maintain what was now looked upon as a high rate of combustion. For conditions under its maximum, natural draught was easily controllable by means of

dampers so that the furnace conditions could be maintained at the most economical point. The principal recommendations of a chimney were its simplicity of operation, its need for comparatively little care and attention, and its being always on the job. Its thermal efficiency was low, but the other advantages offset that in cases where high draught intensity was not needed.

To attain a strong draught by means of a chimney was prohibitive because of the great height involved and the cost. It was therefore necessary to turn to other arrangements, such as an induced-draught system, wherein the suction was created by a fan. The nature of this draught was exactly the same as chimney draught, but it had the advantage of being susceptible to accurate control so that the furnace needs might be readily met. It made possible the installation of economisers to lower the temperature of the escaping gases and effected a saving in fuel.

At the present time a combination of forced draught and either natural or induced draught was being used more and more. Many of the later stokers were operative only with forced draught and were designed for high rates of combustion. Forced draught alone was not a good arrangement for the reason that it created a plenum throughout practically the whole installation and made leaks outwardly through the interstices in the setting likely. By providing a stack of proper height or an induced-draught fan, the necessary suction draught might be supplied to overcome the resistance of the gas passages, leaving the forced-draught fan to supply the pressure necessary to overcome the resistance of the fuel bed. This produced that desirable condition, balanced draught, the pressure above the fuel bed being practically zero or preferably a little on the minus side, namely, the draught gauge should show a slight vacuum.

The amount of fuel burned under a boiler largely determined the amount of steam that would be generated. There was, of course, a more or less well-defined relation between grate area and heating surface, although this varied between rather wide limits. The heating surface of boilers in many instances was being worked far harder than was supposed possible a few years ago. This had been brought about by the introduction of furnaces capable of high rates of combustion, with the result that the temperatures of the escaping gases were too high for the proper economy, rendering necessary the use of feed-water economisers of proper capacity. Such installations were economical as to heat absorption, in interest charges resulting from a smaller investment, and in floor space. The great objection to these types of installations was the complication due to more operating parts, from which the plain chimney of our forefathers was entirely free.

The need for a high intensity of suction draught in connection with forced draught, when high capacities were used, was not generally recognised. When it was realised that the draught required to cause the flow of gas increased as the square of the velocity, it would be seen that this was important. If ½in. in the uptake was sufficient for satisfactory operation at one capacity, doubling the capacity at least doubled the quantity of gas, which meant that the gases must flow twice as fast, assuming that the furnace efficiencies and temperatures were the same in both cases. Theoretically, therefore, it would take four times as much draught, or 2in. as measured by the water column. It was on this rock that many engineers had come to grief in that the attainment of their desire to get a high capacity out of their boilers had not been possible, because after reaching a certain rate of combustion there was a plenum created in the furnace and through the setting, resulting in furnace gases coming out through the numerous interstices owing to the insufficiency of the available suction draught to pull the gases through the boiler and breeching.

The balanced condition was highly advantageous in another way. The greater the difference in pressure between the inside of the setting and the outside, the greater the amount of air drawn in through any cracks or openings, as well as through the porous setting. The less these differences in pressure the less air would be drawn through. All such air was only detrimental and could do no possible good. Every effort should be made to prevent these leakages if the boiler plant was to be run at its highest efficiency.

It was now common to enclose the entire setting in a sheet iron casing, carefully fitted, and made as tight as practicable. Special preparations for coating the outside of brick walls and stopping up cracks were on the market, the goal of all being the same—the exclusion of unnecessary and objectionable air from the interior of the setting.

To attempt to force a grate to burn more fuel than the draught available inevitably resulted in waste and inefficiency through the formation of carbon monoxide instead of carbon dioxide, so that where draught could not be increased beyond a certain point, care must be used not to try to force a higher rate of combustion than could be efficiently maintained.

Every set of boiler and furnace conditions had its most economical point of operation, which could not be exceeded with satisfactory results, but this was true within much narrower limits of simple chimney draught than with either forced or induced draught with the accompanying possibility of widely varying adjustments.

The tendency of modern boiler practice was decidedly toward setting boilers well above the grates so as to give a large combustion space. It was pretty generally recognised that the heat of combustion should all be freed before any of the gases came in contact with the heating surface of the boilers, which in relation to the gases was the cooling surface. A large, high furnace and combustion chamber was essential to attain this end, in addition to which the resistance to flow was minimised.

It was important that the breeching should be as short and direct as possible. Square turns of any sort should be avoided, as all such increased the resistance. The well-known principles governing the flow of water applied almost as universally to the flow of gases. Easy curves should be provided and all corners and dead spaces avoided. Areas must be properly proportioned to the volume of gases to be cared for, and this was particularly true in those plants where high overload capacities were contemplated.

Modern boiler practice seemed to indicate that for the larger and more important plants, at least, something more than ordinary chimney draught was needed. Where simplicity of installation was paramount, simple chimney draught could not be improved upon. As applying to the average plant throughout the country, every means should be used to prevent air from entering the gas passages other than through the fuel bed, and that the loss of draught due to restricted, improperly designed, and obstructed flues be reduced to a minimum, so that the boiler and furnace would be in condition to give the maximum efficiency.

THE USES, OUTPUT, AND MARKET FOR MOLYBDENUM.

IN an article on molybdenum, published in the July issue of the Colorado School of Mines "Quarterly," Golden, Col., Mr. H. Fleck treats of its uses, the market for it, the output, and statistics as follows:—

Molybdenum is used in the form of oxides, ammonium salt and metal. Several tons a year are used in the United States in form of ammonium molybdate as a laboratory reagent in the determination of phosphorus in iron ores, their products, and in fertilisers. The salt finds a further use in fire-proofing fabric. The metal is used in self-hardening steel; from 5 to 10 per cent. is introduced, and the resulting steel is raised in elastic limit and tensile strength, and possesses greater toughness in addition to the former property. Wire made from it is said to have greater elongation and high tensile strength. Other uses are in large castings; in gun barrels, in which it is prized for its resistance to corrosive gas action; in armour plate; in armour-piercing shells; in motor-car steel, and in magnets. Equal parts of molybdenum and chromium introduced into steel are proclaimed more preferable for many of the above uses, especially self-hardening steel. Two to 5 per cent. of molybdenum and 10 per cent. chromium, with little or no carbon, are said to make steel acid resisting to a great degree. Nickel-molybdenum-ferro-alloys also find use. The tensile strength of molybdenum wire is given at 200,000-270,000lbs. per square inch, as compared to tungsten with 480,000-580,000lbs. per square inch. Molybdenum wire-wound electric furnaces have special claims made for them. A thermo-couple which uses the metal has been described recently. The lower oxides of molybdenum are highly coloured. Their use is recorded in colouring

leather, rubber, and porcelain. A soluble variety is used as a substitute for indigo. In some form molybdenum is added as a preservative to certain smokeless powders.

Prior to 1900 little use was made of the metal. From 1900 to 1905 a gradual increase in the production of molybdenum took place. Then there was a decline until the opening of the war, when demand increased rapidly with rising prices, and to-day astonishing figures record a marked advance. Not long ago a prominent engineering journal scoffed at the alleged importance of molybdenum, but recently the same journal published an appeal from the British Imperial Engineering Institute to Canadian producers of molybdenum ore. This is the history of the rare metals. Their growing utility cannot be denied. It must be remembered that all useful metals had their modest industrial beginning. It has been stated frequently that dull markets were due to uncertain output. This may have been so before modern concentration methods were used, but this reason is no longer valid. When consumers consent to pay the price which makes the mining and concentrating enterprise worth while, the supply will prove adequate to the demand.

The principal production has been as follows: The Australian output in 1902 was 15 tons, valued at £1,841; in 1903 it was 29 tons, valued at £4,450; and in 1904 it was 25 tons, valued at £2,726. The New South Wales output in 1911 was 20·65 tons, valued at £2,591; in 1912 it was 56·5 tons, valued at £3,706, and in 1913 it was 73 tons, valued at £6,400. The New South Wales output in 1914 was 61 tons. The Queensland output in 1911 was 99·5 tons, valued at £13,279; in 1912 it was 102·3 tons, valued at £17,349, and in 1913 it was 57 tons, valued at £16,185. Not counting the small annual production of Norway and scattering parcels, the above figures represent most of the best years of molybdenum production. There is little doubt that 1915 and 1916 will show astonishing figures, record output, and prices, together with considerable development in hitherto neglected fields. It is not safe to predict a continuation of these, however, for an indefinite period. Substantial prosperity in rare metals has been marked by a slower growth.

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Vapour electric converters. British Westinghouse Electric and Manufacturing Company. 12160.

MELTING ALUMINIUM CHIPS.

BULLETIN 108 on "Melting Aluminium Chips," by H. W. Gillett and G. M. James, recently issued by the U.S. Bureau of Mines, discusses the causes of the high loss in the usual method of melting aluminium chips, and shows that the difficulty of getting the tiny globules of molten metal, resulting from the fusion of the very fine chips, to coalesce when covered with a skin of oxide and dirt, is apparently the main cause for low recoveries. Two methods of melting can be successfully used to promote coalescence. In one method the chips are kept just above the fusion point and the globules made to coalesce by hand puddling, which breaks through the skin and makes the globules unite. In this method melting is best done in an iron pot heated by oil. The other is by the use of a flux, which dissolves off the skin of dirt and oxide, producing clean globules which can unite. The flux suggested is 85 per cent. common salt, 15 per cent. fluorspar, used in large amount (20 to 30 per cent. of the weight of the chips), and mixed with the chips before charging. Much higher temperatures are required by this method than by the puddling method, so the iron-pot furnace is not practicable, and melting is best done in graphite crucibles or in a reverberatory furnace. The flux method does not require the constant hand puddling of the other method. Since the presence of dirt and oxide causes low recoveries, the necessity for care and cleanliness in the collection and storage of chips is emphasized. Chips wet with cutting compound will oxidise superficially on storage, but by drying the chips by centrifuging this can be prevented.

METAL QUOTATIONS.

TUESDAY, DECEMBER 5th.

Aluminium ingot	— per cwt.
,, wire, according to sizes, &c. .....from	— ,,
,, sheets ,, ,, ... ,,	— ,,
Antimony	£95/–/– per ton.
Brass, rolled	1/5$\frac{5}{8}$ per lb.
,, tubes (brazed)	1/8$\frac{3}{4}$,,
,, ,, (solid drawn)	1/6$\frac{3}{4}$,,
,, ,, wire	1/6$\frac{1}{8}$,,
Copper, Standard	£152/–/– per ton.
Iron, Cleveland	87/6 ,,
,, Scotch	— ,,
Lead, English	£32/5/– ,,
,, Foreign (soft)	£30/–/– ,,
Mica (in original cases), small	6d. to 3/– per lb.
,, ,, ,, medium	3/6 to 6/– ,,
,, ,, ,, large	7/6 to 14/– ,,
Quicksilver	£17/12/6 per bottle.
Silver	36$\frac{1}{16}$d. per oz.
Spelter (American)	£57/–/– per ton.
Tin, block	£188/–/– per ton.
Tin plates, I.C.	27/6 per box.
Zinc sheets	£100 per ton.

Membership of German Trade Unions.—Since the beginning of the war the German trade unions have, says "The Times," lost 60 per cent. of their members. In June, 1914, the membership of the unions amounted to 2,482,046, but by the end of 1915 this number had dropped to 982,863.

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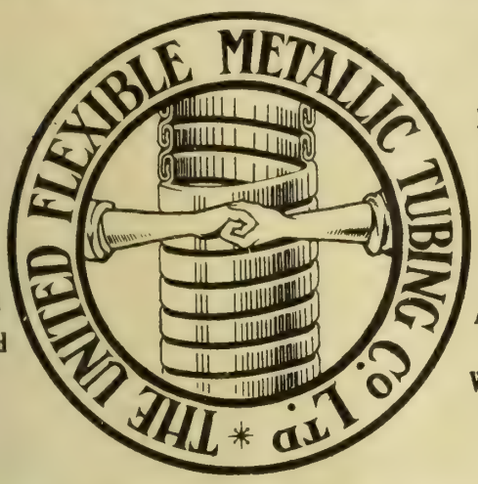

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By JOHN S. G. PRIMROSE, A.R.T.C., A.I.M.M., M.I.M.
Lecturer on Metallurgy, and demonstrator on Metallography at the Royal Technical College, Glasgow.

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Every Iron and Steel Works should be provided with a metallographic laboratory with a suitable equipment in which, by Scientific methods, the daily working may be controlled and improved, and that this may be efficient, every worker should be familiar with the principles on which the researches are based. This book has been prepared for the use of those who are commencing the study of metallography. The work is a thoroughly practical one, theoretical considerations being made as brief as possible. The contents comprise exhaustive chapters on Microstructure of Iron and Steel; Constitution of Iron and Steel; Heat Treatment of Iron and Steel; Micrographic Examination of Failures; Metallographic Apparatus and its Manipulation.

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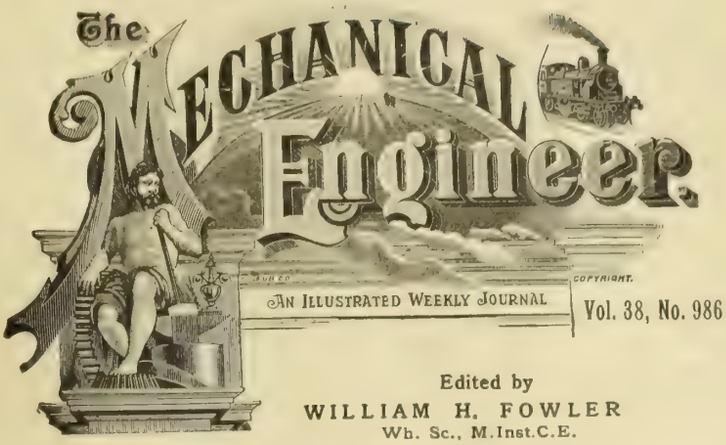

Edited by
WILLIAM H. FOWLER
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Organisation of the Iron, Steel, and Engineering Industries.

AN important report, which we reproduce on another page, has been issued by the committee appointed by the leading Clyde firms, at a meeting, held on August 4th last, to consider how best to secure united action so as to deal in a comprehensive and imperial manner with all important questions affecting the iron, steel, engineering, shipbuilding, and allied industries. The suggestions put forward to secure the end in view, although preliminary and admittedly incomplete, provide ample scope for immediate action, and every responsible engineer should consider them with a view to promote a sound public opinion on post war conditions. The outstanding points, on which the committee base their report, are that in the first place increased production of wealth will have the greatest effect on general prosperity, and that unless industrial concerns are raised to the highest pitch of efficiency, and the largest available output obtained, all other measures will be of secondary importance. On this there cannot, we think, be any difference of opinion. The nation's load of indebtedness can only be borne and liquidated by the greater production of wealth. It is equally obvious that increased productivity cannot be attained unless there is more cordial co-operation between employers and employés, so as to secure higher efficiency, both of machinery and organisation, unless the false doctrine that limitation of output creates employment and raises the wage standard is entirely discarded. This doctrine is opposed to every axiom of economics, but is equally opposed to the interests of the employés themselves. Every legitimate increase of output should be encouraged and payment by results should, as far as possible, be the basis of reward for labour. Further, the scales "fixed should be such

as to ensure for all willing workers a comfortable standard of living," and once established, increase of earnings, due to increased output should be encouraged in every way. Enhancement of earnings following increase of production should not be "made a ground for rate cutting." These points, it will be seen, touch the interest of employers and employés alike, and since the success of their working depends on mutual confidence, any organisation for putting them into operation must also be of a co-operative character. Without it the best intentions and efforts are doomed to failure. The report indicates in a general way the objects which such an organisation should have in view. These are based on the assumption, in the first place, that the Government in future will take an active part in "encouraging by every means in its power the development of the industries of the country," and, therefore, it will be the duty of the organisation in the first place to inform and direct the Government and its departments regarding matters calling for action in the interests of industry. Secondly, to deal with questions affecting labour conditions, internal organisation, and disabilities with a view to securing increased efficiency. Thirdly, "to educate and inform the public opinion in accordance with its recommendations and findings." Finally, it is suggested that a Ministry of Industry should be appointed and that for this appointment no individual "retaining a connection with either the employers' or employés' side of industry is desirable"; further, that the appointment should not be given to "an individual having only a legal or political qualification, or to a permanent official, while his appointment or retiral should not be dependent on a change of Government." It must be admitted that an individual free from these disqualifications would be very difficult to find, especially when to the possession of these negative virtues he would probably in the exercise of his functions require the patience of a Job and the will of an autocrat. The Government has not appointed a "Minister of Industry," but a "Minister of Labour," and though the holder of the appointment will not conform to the above qualifications, we nevertheless welcome it, as well as that of two other labour leaders. It will, at all events, impose on the representatives of labour a responsibility from which in the discussion of labour questions and troubles they have hitherto been largely free, and which accounts to some extent for the frequent breaches of agreement between capital and labour during recent years, and in the presence of which, efficient co-operation is impossible.

Glass Manufacture.—A department of glass technology at the University of Sheffield has, says "The Times," been organised with the financial support of the Advisory Committee of the Privy Council for Industrial Research, of the Ministry of Munitions, and of the glass manufacturers of South Yorkshire. An actual glass factory will be established, in which operations will be done on a large, semi-commercial scale. The model factory will be equipped with pot furnaces and a small tank furnace and a series of experimental furnaces, including a number of electrically-heated ones and some heated by gas.

THE INTERNAL-COMBUSTION MOTOR FOR TRACTION ENGINES.*

BY A. A. POTTER AND W. A. BUCK.

AT the present time, over 100 manufacturing concerns in the United States are building traction engines driven by internal-combustion motors. The designs differ greatly; some have motors with horizontal cylinders, others with vertical cylinders. In some designs the power of the motor is delivered to one wheel, in others to two, and in still others to all four wheels; several designs are of the so-called "creeping grip" types.

The development of the traction engine for agricultural purposes has been along lines entirely different from those of the automobile. The early engines developed 60 h.p. to 80 h.p. on the brake and 30 h.p. to 40 h.p. on the drawbar; they were expensive, complicated, and unsuited for any but the largest farms of the country. The present tendencies of manufacturers are to build smaller engines and to standardise the product.

Object of Investigation.—The purpose of this investigation was to determine the fuel economy and thermal efficiency of a great variety of traction-engine designs, to find out the practicability of the fuels heavier than gasoline for traction-engine use, and to compare the rating, valve setting, timing and other details of commercial traction engines. Particulars of the motors tested and of the fuels used are given in Table I.

General Conclusions.—From the results of this investigation the authors have derived the following general conclusions:—

(*a*) The 4-cylinder motor is better adapted for belt work on account of the greater number of impulses per revolution.

(*b*) The single-cylinder motor and the 2-cylinder motor operate better than 4-cylinder motors with fuels heavier than gasoline.

(*c*) Carburetters now used are satisfactory for gasoline, but a carburetter jacketed with heat from exhaust gases should be employed when operating with kerosene or with the heavier fuels.

(*d*) The ordinary automobile motor is too light for traction-engine work. The traction-engine motor should operate at lower piston speeds than the automobile motor. Motors operating at piston speeds of 700ft. to 900ft. per minute are giving satisfaction.

(*e*) The vertical types of motors are preferable on account of greater accessibility, longer lift, and better balance.

(*f*) The valve-in-the-head type of motor has the more efficient combustion space, and is to be preferred to the T-head or L-head types.

(*g*) The combination of the forced feed and splash oiling system gives good results.

(*h*) The jump-spark system, on account of its mechanical simplicity, is the best system of ignition for traction engines.

(*i*) The fuel-economy range is from about 1·30lbs. per shaft horse-power per hour at one-fourth load to about 0·71b. per hour at full load. The fuel consumption in pounds per shaft horse-power per hour is very nearly the same for both gasoline and kerosene.

(*j*) The thermal efficiencies at full load vary from 14·88 to 19·41 per cent. for gasoline fuel, and from 13·7 to 15·97 per cent. for kerosene.

Results of Tests.—The paper includes a table giving results of the tests relating to fuel consumption and thermal efficiency at various loads, and from the former the curves of Fig. 1 have been plotted.

Conclusions from Tests.—The lower fuel economy shown for engine A as compared with engine B (the same engine) was due to the greater spark advance used in operating engine A, when more cooling water had to be injected into the cylinder with the fuel to prevent pre-ignition. Water injection had to be used also during the tests of engines D, E, and F with gasoline fuel.

In the case of several engines the valve setting had to be changed before satisfactory operating conditions could be secured. In one case the preliminary tests indicated that the carburetter was too small for the engine. Some companies in such cases remove several balls from the auxiliary air valve,

* Abstract of paper read at the annual meeting of the American Society of Mechanical Engineers, New York, December 5th to 8th, 1916.

a practice which is followed by poor fuel economy of the engine. These experiences indicate the poor inspection and testing facilities prevalent with some manufacturers of traction engines.

TABLE I.—*Particulars of the Traction Engine Motors Tested and the Fuel Used.*

Engine	Type (all 4-stroke cycle)	Ignition System	Lubrication System	Carburetor	Cooling System	Governor	Fuel: Gasoline or Kerosene	Fuel: Specific gravity	Fuel: Heating Value, B. t. u. per lb.	Rating, b.h.p	Bore, in.	Stroke, in.	Rev. per min.
A	hor., twin, 2-cyl.[1]	high-tension, magneto	mech op. sight-feed oilers	....	pump	throttling[2]	K	0 809	19,700	60	. .	.	. . .
B	(same motor as A, but	tested when new)		.....	...	. . .	K	0 800	19,680	60	.	...	...
C	vert. L-head,[1] 4-cyl.	high-tension,[3]	splash & mech op sight feed	Bennett	pump	throttling[2]	G K	0 739 0 786	19,670 19,500	65	7¼	9	500
D	vert., T-head, 4-cyl,[1]	high-tension[3]	sight-feed pump	Bennett	pump	diaphragm[4]	G	0 741	19,000	50	6	7	650
E	hor., opposed, 4-cyl[1]	high-tension[3]	st feed pump splash	Kingston	thermo-syphon	throttling[2]	G	0 735	17,680	50	6½	7	500
F	hor., opposed, 2-cyl.[1]	dual	mech st feed oiler	Rayfield	thermo-syphon	throttling[2]	G	0 730	20,600	40	8	9	350
G	vert., L-head, 4-cyl.[1]	high-tension[3]	pump splash	Bennett	pump	throttling[2]	G	0 737	20,000	35	5	7	700
H	hor., L-head, 4-cyl.[1]	high-tension[3]	mech st feed oiler	..	pump	throttling[2]	K	0 789	19,900	25	5¼	8	575
J	hor., opposed, 2-cyl.[1]	high-tension[3]	pump splash	Kingston	thermo-syphon	throttling[2]	G	0 747	19,550	25	6½	7	570
K	vert., L-head, 4-cyl.[1]	high-tension[3]	pump splash	Bennett	pump	throttling[2]	G	0 737	20,000	20	4¼	5¾	800
L	hor., single-cyl.[1,5]	low-tension[6]	sight-feed oiler	.....	hopper	throttling[2]	K	0 805	19,280	16	8	12	400
M	hor., L-hd., 2-cyl., opp[1]	Kingston dual b.-t.	mech. st. feed oiler	Kingston	pump	throttling[2]	G	0 738	20,290	20	5¼	7	650 720

[1] With mechanically operated inlet and exhaust valves.
[2] High-speed throttling type of governor that regulates the quantity of mixture.
[3] With K-W impulse starter magneto.
[4] Diaphragm type, using pressure of circulating water to control the speed.
[5] Valve in the head.
[6] Make-and-break system using an Accurate oscillating magneto.

The advantages of the kerosene engine are offset to a greater or less degree, depending upon the operator, by the added trouble in handling. The life of the motor will also be somewhat shortened when using kerosene fuel. To this should be added the lower reliability with the heavier fuel. In some work done by traction engines reliability is the main factor. Due to the high price of gasoline, new carburetters are being placed on the market which handle kerosene very satisfactorily, and eventually it will be used more as a fuel for traction engines than will gasoline.

A study of the valve timing of the different motors in these tests shows no uniformity, except that the majority of the motors are so timed that the inlet valve does not open until after the exhaust valve is closed. The timing given in Table II. is offered as a result of the authors' study and experience with traction engines.

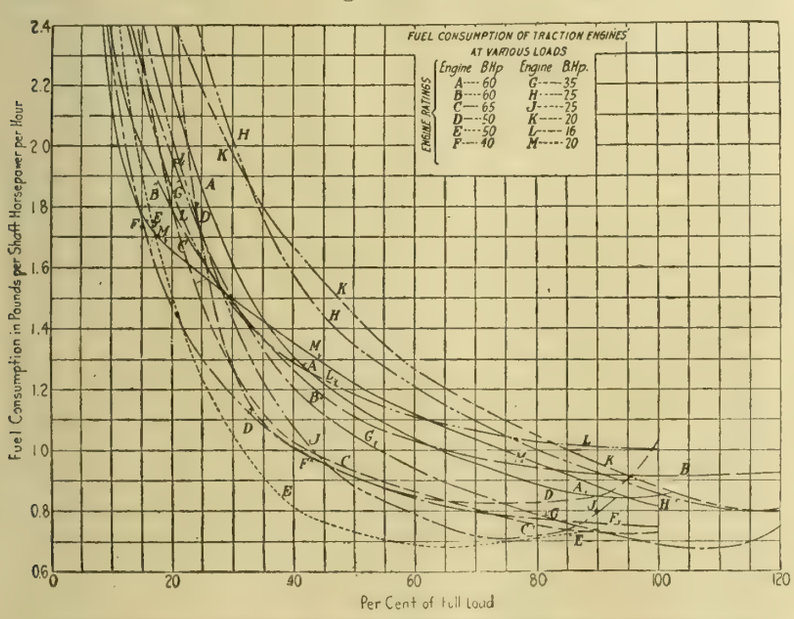


FIG. 1.—CURVES OF FUEL CONSUMPTION OF TRACTION ENGINES AT VARIOUS LOADS.

TABLE II.—*Valve Timing for Motors of Traction Engines.*

Speed of Motor, r.p.m.	Exhaust Valve: Opens before outer centre.	Exhaust Valve: Closes after inner centre.	Inlet Valve: Opens after inner centre.	Inlet Valve: Closes after outer centre.
	Degrees.	Degrees.	Degrees.	Degrees.
200	20 to 25	0 to 3	0 to 3	15 to 20
300	22 to 27	0 to 5	2 to 5	15 to 20
400	27 to 32	2 to 5	2 to 7	15 to 20
500	30 to 35	4 to 8	5 to 10	18 to 23
600	35 to 40	4 to 8	8 to 12	18 to 23
700	40 to 45	6 to 10	10 to 12	20 to 25
800	45 to 50	6 to 10	10 to 12	20 to 25

From Fig. 1 it is evident that several of the motors are not rated at the capacity for best efficiency. The motors represented by tests G, H, K, and M are underrated, E and J are overrated, while A, B, C, and F are properly rated.

RIVETED JOINTS.

AN exhaustive paper entitled "The Partition of the Loads in Riveted Joints," by Cyril Batho, M.Sc., B.Eng., Assistant Professor of Applied Mechanics, McGill University, Montreal, is given in the November issue of the Journal of the Franklin Institute. The author states that riveted joints occur in many types of construction, and it is therefore of considerable practical importance to determine the exact manner in which they act, in order that a rational basis may be given for their design. The subject has attracted the attention of many experimenters, their investigations being mainly directed to a determination of the resistance of joints to rupture and of the frictional resistance to slip. Attempts have also been made to determine the tension in the body of a rivet due to its contraction on cooling, and Frémont has made an exhaustive study of the actual process of riveting and its effects upon the strength of the joint. None of these experiments, however, have indicated very clearly the action of a riveted joint under working loads—*i.e.*, before permanent deformations of the plates or rivets have occurred. Very few attempts have been made either experimentally to determine or theoretically to estimate the partition of the load among the rivets under working conditions. It is usually assumed, in designing a riveted joint, that the load is equally divided among the rivets. That this cannot be true in joints as usually designed has been generally recognised by writers on bridge design, and illustrated by experiments on the distortion of lath and india-rubber models.

The writer's attention was first directed to the subject by the results of a few readings taken with a Howard gauge on the cover plates of a large riveted splice tested by Prof. H. M. Mackay, of McGill University, for the Quebec Bridge Commission. These appeared to indicate that the rivets in the end rows received by far the greater portion of the load, and suggested to the writer that the actual partition of the load in any joint could be determined by extensometer

measurements on the cover plates of the joint. It was first necessary to determine whether or not the strains of the outer surfaces of the cover plates could be used to obtain the mean strains in the cover plates. This was shown to be the case by an experiment given in the paper, and experiments were commenced upon a series of butt joints having a single line of rivets. While making these experiments it occurred to the writer that the results might be interpreted and the partition of load worked out theoretically by means of the Principle of Least Work. This proved to be so, and further experiments verified the theory in every particular.

The paper is divided into two parts. Part I. shows how, by means of the Principle of Least Work, a series of equations may be obtained, giving the load carried by each rivet in any form of riveted joint in terms of a quantity K, which, if the rivets are in shear, depends upon the manner in which work is stored in the rivets; or, if they act by frictional hold on the plates, depends upon the work stored in the parts of the plates thus held. Part II. gives the results of a series of experiments upon different forms of joints having a single line of rivets and loaded in tension, which confirm and illustrate the theory and show how the quantity K may be determined. The following is a summary of the principal contents of the present paper:—

1. It is shown that a riveted joint may be considered as a statically indeterminate structure, and that a series of equations may be obtained for any joint by means of the Principle of Least Work, giving the loads carried by each of the rivets in terms of a quantity K, which depends upon the manner in which worked is stored in, or by the action of, the rivets.

2. This theory is applied to various types of joints, and the modifying effects of non-uniform distribution of stress in the plates, unequal partition of the load between the two cover plates, and a difference in the modulus of elasticity of the middle plate and the cover plates are also considered.

3. It is shown experimentally that extensometer measurements on the outer surfaces of the cover plates of a riveted joint are sufficient for the determination of the mean stresses in the plates, and that the partition of the load among the rivets may be determined from such measurements. It is also shown that, at any rate after the first few loadings, the distribution of strain in the plates of a joint is not altered by repeated loadings.

4. It appears from 3 that if there is any frictional hold between the plates, it acts only over those portions in the immediate neighbourhood of the rivets. All the experiments tend to show that friction does not play an important part, but further experiments are necessary on this point.

5. Experiments made on a number of specimens having a single line of rivets and loaded in tension give results in close agreement with the theoretical considerations. They also show that the longitudinal stresses in a portion of the cover plate between two consecutive rivets are a minimum along the line of rivets, rising to a maximum at the edges of the plates.

6. The experiments show that the value of K for a joint having a given ratio of width of cover plate to rivet pitch and a given number of rivets varies approximately directly as the load and inversely as the area of the rivets. An empirical rule is given for its value in joints similar to the experimental specimens, but a more general rule cannot be given until further experiments have been made. A theoretical estimate is made of the value of K for a rivet acting in shear, and the result is shown to be within the range of the experimental values.

7. Both the experimental results and the theoretical deductions show that: (*a*) in a double-cover butt joint having a single line of rivets, the two end rivets and the two rivets on each side of the junction of the middle plates take by far the greater part of the load at all loads within that causing permanent deformation of the plates or rivets, the actual proportion decreasing slowly as the load increases; (*b*) if, in such joints, the total area of cross-section of the cover plates is equal to that of the middle plates, these four rivets take equal loads, but if it is greater the end rivets take greater loads than the others, the difference increasing as the area of the cross-section of the cover plates increases; (*c*) if two plates of uniform width and equal thickness are connected by a single line of rivets to opposite sides of a gusset plate of uniform width, the first and last rivets take the greater part of the load, but if the gusset plate increases in width from the first to the last rivets, the partition of load is more uniform.

The results already obtained allow the general manner of partition of load in any riveted joint, in which there is no eccentricity of connection, to be estimated, and it is hoped that, when further experiments have been given general laws for the value of K, it will be possible to predetermine the exact load that will be carried by each rivet. The practical value of this is obvious.

ORGANISATION OF IRON, STEEL, ENGINEERING, SHIPBUILDING, AND ALLIED INDUSTRIES.

THE following resolutions were unanimously passed at a meeting of representatives of Scottish iron, steel, engineering, shipbuilding, and allied industries, held on August 4th, 1916, under the chairmanship of the Right Honourable the Lord Provost of Glasgow, Sir Thomas Dunlop, Bart.

Resolution (1): That in view of the unprecedented situation created by the war and the uncertainty of the future, this meeting is of opinion that all iron, steel, engineering, shipbuilding, and allied industries in this country should endeavour to come together in some strong central organisation capable of dealing in a comprehensive and imperial manner with all important questions affecting these and allied industries, which will certainly arise in the near future.

Resolution (2): That a Preliminary Committee be appointed to report at an early date to this meeting of the industries represented as to the nature, scope, and object of an organisation which could deal with the conditions governing the industries in question, and with the Government regarding any measures old or new which may affect these industries after the war.

The following were appointed members of the Preliminary Committee, viz.:—

A. W. Anderson (Urquhart, Lindsay, & Co., Ltd., Blackness Foundry, Dundee), Archd. Barr, D.Sc. (Barr & Stroud, Ltd., Anniesland, Glasgow), Andrew S. Biggart (Sir Wm. Arrol & Co., Ltd., Dalmarnock Ironworks, Bridgeton), Archd. Colville (David Colville & Sons, Ltd., Dalzell Steel and Ironworks, Motherwell), Sir John Cowan (Redpath, Brown, and Co., Ltd., St. Andrew Steelworks, Albion Road, off Easter Road, Edinburgh), Alex. Gracie (Fairfield S. and E. Company, Ltd., Govan, Glasgow), Andrew Lamberton (Lamberton & Co., Sunnyside Engine Works, Coatbridge), J. H. Mathieson (Alex. Mathieson & Sons, Ltd., 11, East Campbell Street, Glasgow), A. K. M'Cosh (William Baird & Co., Ltd., 168, West George Street, Glasgow), F. L. M'Kinnon (William M'Kinnon & Co., Ltd., Spring Garden Ironworks, Aberdeen), Noel E. Peck (Barclay, Curle, & Co., Ltd., Clydeholm Shipyard, Whiteinch), Hugh Reid (North British Locomotive Company, Ltd., 110, Flemington Street, Springburn, Glasgow), J. R. Richmond (G. & J. Weir, Ltd., Holm Foundry, Cathcart), T. Cuthbert Stewart (Stewarts & Lloyds, Ltd., 41, Oswald Street, Glasgow), Wm. Rowan Thomson (David Rowan & Co., 231, Elliott Street, Glasgow).

At the first meeting of the Committee it was agreed to co-opt Mr. Wm. Weir, Director of Munitions in Scotland, Ministry of Munitions, 39, Elmbank Street, Glasgow. The Preliminary Committee has held nine meetings, and now presents its report.

The following general points it is thought are of outstanding importance in the consideration of the question:—

(1) (*a*) It is assumed that the Government will take a more active part in the future in encouraging, by every means in its power, the development of the industries of this country.

(*b*) After consideration of the various aspects of the probable post-war conditions, the Committee is of opinion that the factor that will have the greatest effect on the prosperity of the country in general, and the industries in which we are interested in particular, and that will overshadow all other factors, is the question of increased production. Unless the capacity of efficiently-equipped industrial concerns is utilised to the fullest extent, and the largest available output is attained, all other measures of assistance or regulation will be of secondary value in attaining the expansion and pros-

perity of our industries and the comfort and well-being of those employed in them.

(*c*) Increased productivity can only be attained by a more cordial co-operation between employers and employés than has existed in the past; by efficient equipment and organisation on the one hand, and, on the other, by the abolition of all restrictions and practices limiting output.

The existing policy of limiting output, and of refusing in many cases any system of payment by results so that employment may last longer or that more men may be employed, is agreed to be economically unsound and inimical to the best interests of the Empire.

(*d*) In order to secure the foregoing, it is essential that in the remuneration of employés some form of payment by results should be adopted wherever possible, with basis rates, compatible with the productive effect of labour, fixed on such a scale as will ensure for all willing workers a good and comfortable standard of living. Once these basis rates have been equitably fixed and established, an increase in earnings, due to increased results, should be encouraged in every way; and workmen should have the security given them, that any enhancement of their earnings following increased production, will not be made a ground for rate-cutting, as the whole success of the system must inevitably rest upon mutual confidence.

(*e*) In view of the foregoing considerations, any organisation which may be instituted should be prepared to co-operate with labour, as without such co-operation and assistance the desired result will be difficult of attainment.

(*f*) An increased supply produced under the improved conditions outlined above may be confidently expected to create a correspondingly increased demand, and that quite apart from the increased demand which it is widely anticipated will arise after the war. At the same time, attention and efforts must be directed to maintaining and extending existing markets and securing additional markets.

(2) Supplementing these general considerations, the following is an indication, not necessarily exhaustive, of the objects that any organisation which may be instituted should have in view, viz.:—

(*a*) To direct the attention of the Government and its Departments, for their information and guidance, to matters requiring consideration and action in the interests of the industries concerned, and to initiate and review legislative proposals on commercial, industrial, and economic matters.

(*b*) To deal with questions affecting the labour conditions and internal organisation and disabilities of the industries concerned, with a view to securing increased efficiency from an imperial and national point of view.

(*c*) To educate and inform public opinion in accordance with its recommendations and findings.

(3) As examples of the questions, under these headings, which might have to be dealt with, the following have been mentioned, but it is to be clearly understood that the Preliminary Committee express no opinion on the merits of any particular point. The examples are only given as illustrating in a general way the questions which might arise for consideration, viz.:—

(*a*) Consideration of all conditions affecting trade and industry proposed to be embodied in the terms of peace or in any treaty.

(*b*) The effect on industry of regulation of imports and exports by means of tariffs, subsidies, or prohibitions.

(*c*) The effect of existing banking methods on industrial enterprise.

(*d*) The question of facilities and rates for transport by rail, road, or water.

(*e*) The safeguarding of existing and the securing of additional markets.

(*f*) The establishment of efficient consular services in relation to foreign trade.

(*g*) Questions relating to sickness and unemployment, insurance, and pensions.

(*h*) Means of giving workpeople a continuing interest in the prosperity of the industry in which they are employed.

(*i*) Remuneration of workpeople according to output, by piecework, premium bonus, or other system of remuneration, and the grading of labour according to skill and ability.

(*k*) Rates of wages, working hours, and demarcation of work between skilled and unskilled workpeople, between men and women, and between different skilled trades.

(*l*) To consider present promiscuous methods and times of making general advances or reductions of wages.

(*m*) The apprenticeship question—how affected by the experiences of the war and from all points of view.

(*n*) Questions affecting the employment of women workers.

(*o*) Social amenities of workshops, and the well-being of young people engaged in industries.

(*p*) The effect on the industrial efficiency of the country of existing or pre-war restrictions of freedom of management and control.

(*q*) The provision of machinery for avoiding strikes and lock-outs, and for settling questions which arise between employers and employed.

(*r*) The review of the procedure of employers' associations, trade unions, or other combinations of employers or workpeople where such tends to interfere with the liberty of the subject, without national benefit.

(*s*) Questions of scientific and technical education.

(*t*) Industrial research and experimental investigation.

(*u*) Whether it is desirable, in view of the grave disadvantages which have arisen in the past from the failure of individual employers and individual workmen to carry out agreements made on their behalf by their accredited representatives, that some method of making the associations of employers and employés responsible for their members should be adopted.

(4) The questions to be dealt with fall into two divisions:—

(*a*) Such questions affecting labour as are best dealt with directly between specific classes of employers and their employés.

(*b*) Questions in which labour is only indirectly interested and which can be dealt with separately by employers.

(5) Questions which fall under the *first* category have in the past been dealt with between employers' associations and trade unions with a fair measure of success. In view of the undesirability of multiplying organisations, and of the value of the existing staffs with their experience, knowledge, and records, it appears most natural and practicable to take advantage of existing organisations and improve and extend them to deal with such questions. With this object, existing employers' organisations should include all employers engaged in the industry and within the district covered by them. Where, in any district or industry, no association exists, an association should be formed.

(6) As regards questions which fall under the *second* category, it is considered that employers who belong to associations with constitutions which enable them to deal with such questions are (subject to the proposal dealt with later) already provided for. In other cases either the existing associations should extend their constitutions to cover such questions, or employers should join some existing association (for which they are eligible) which covers the ground, or, as an alternative only to be adopted in the last resort, a new association should be formed with an appropriate constitution. In the foregoing arrangement it is felt that associations should neither as regards the industries or areas covered be so large as to be unwieldy nor so small as to be parochial.

(7) In order to co-ordinate the activities of the various organisations; to obtain due recognition of properly-constituted employers and employés' associations; to confirm in or endorse voluntary agreements between employers and employés, and, where desirable, to give legal effect to the recommendations of these associations, it is considered that some central organisation is necessary which should have Governmental recognition to give it weight and authority.

(8) It is suggested that the central organisation should take the form of a National Advisory Council of Industry consisting of two bodies, viz.: representatives of employers and representatives of employés, who would meet either separately or together, as the nature of the questions to be considered might require—the joint meeting being always (and the meetings of the separate bodies as required) presided over by the Minister of Industry mentioned hereafter. The employers' representatives should be elected by the various employers'

organisations, in number and proportions to be determined with possibly additional employers' representatives nominated directly by the Government. The employés' representation should be similarly determined. Government Departments might also be represented at the joint or separate meetings, or might, if thought desirable, constitute a separate body available for joint meetings. This Governmental representation would safeguard the interests of the State and the community as against the personal interests of the employers and the employés.

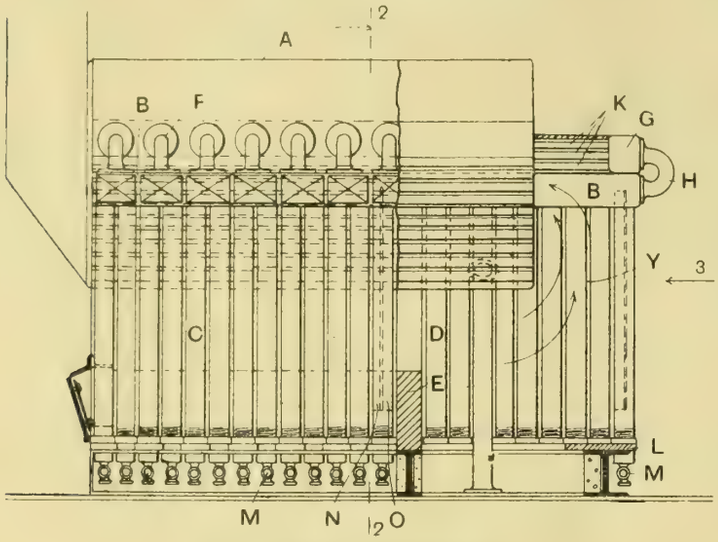


FIG. 1.—DEIGHTON'S STEAM BOILER.

(9) In actual practice it might be found desirable that the National Advisory Council should be chosen from amongst local councils formed for large industrial areas; for example, Scotland could form one such area. As some industries are federated over the whole country, and others are only associated locally, this point requires careful consideration. In any case, it appears desirable that local associations should federate with other associations in the same industry for certain purposes at least, over as large an area as possible.

(10) It is suggested that a Minister of Industry should be appointed, and in this connection the appointment of an individual retaining a connection with either the employers' or the employés' side of industry is undesirable, as is the appointment of an individual having only a political or a legal qualification. It is suggested that while a Minister of Industry should not be a permanent official, neither should his appointment nor retiral be dependent on a change of Government. Such a minister would form the connecting link between the Government and the central organisation described in the eighth paragraph.

The Preliminary Committee considers that the foregoing report covers the terms of the resolution under which it was appointed, but in view of the desirability of indicating steps which might be taken to give practical effect to its report (should it meet with the approval of those to whom it will be presented) the following further suggestion is made, viz.: That a Temporary Committee be appointed, representative of the industries concerned in Scotland, to take steps to put into practical effect the general principles enunciated.

Without desiring to lay down definite lines of action or to limit the activities of such a committee, it is suggested that such steps should include the following, viz.:—

(1) Consultation with representatives in other districts of the industries concerned as to whether such districts are in sympathy with the principles laid down in this report, and, if so, to take common action in the movement.

(2) If so agreed, the formation, in conjunction with or through local associations, of local Councils or branches of a National Advisory Council of Industry.

(3) If so agreed, the formation in conjunction with other districts of a National Advisory Council.

(4) In conjunction with other districts to lay these proposals before the Government and endeavour to enlist its support in the appointment of a Minister of Industry and the formation of a National Advisory Council of Industry.

(5) To bring the substance of this report before individual firms and associations with a recommendation that non-associated firms should join existing associations or, where none exist, that associations be formed.

DEIGHTON'S STEAM BOILER.

THE accompanying illustrations show a design of combined multi-tubular and water-tube steam boiler, the invention of Mr. William Deighton, Beechwood, Moortown, Leeds, Fig. 1 being a side elevation partly in section. Fig. 2 a section on the line 2. 2, Fig. 1 looking in the direction of the arrow, and Fig. 3 an end view of Fig. 1 looking in the direction of the arrow 3. The multi-tubular portion A has longitudinal headers B (having openings for examination) on either side somewhat below the horizontal centre line, with side walls of tubes C for the fire area and continuation walls of tubes D for the combustion chamber, the approximate dividing line of the two being a fire bridge E, all of such tubes connecting with the headers B, which are in turn connected with the generator portion by curved pipes F. A cross-header G, also having openings for examination, connected with the headers B by curved pipes H, carries an end wall of tubes J, the enlarged portion of the combustion chamber Y extending beyond the generator portion A, being roofed in by horizontal water and steam pipes K, connecting the tube plate of the portion A with the header G so that a flat arched roof portion is provided over which is placed a covering of firebrick. The lower ends of the tubes C, D, and J are plugged and are held in bracket plates L, and are provided with blow-off cocks M. These tube ends are so arranged as to be readily removable by drawing outwardly after removal from the headers. The plates L are secured to longitudinal or cross girders. By mounting the entire generator upon longitudinal and cross girders, it is self-contained and capable of being readily moved and set as a whole. The tubes C, D, and J may be of the "Field" or like type for circulating purposes. They are, as shown in Fig. 4, divided by two diaphragms N O into three chambers P P and Q, the

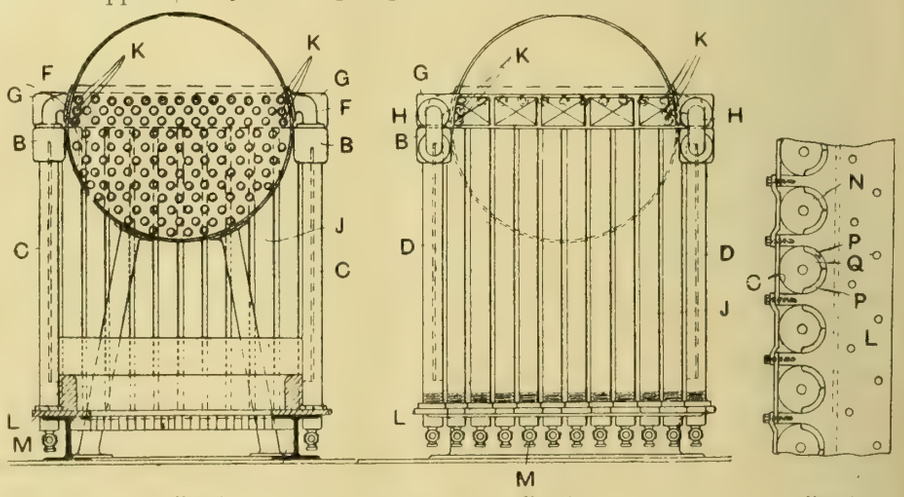


FIG. 2. FIG. 3. FIG. 4.
DEIGHTON'S STEAM BOILER.

former P P serving as the uptakes, being open at each end into the latter Q which serves as the downtake. The diaphragms N O being curved enables a central feed pipe, connected with a feed inlet or cock, to be introduced if desired. The back end of the generator portion A is supported by two columns passing through the combustion chamber. The front end is carried by a saddle. The spaces between the tubes forming the walls are closed by suitable laggings or refractory material. With the general construction described a generator low in height and adapted particularly for shallow draught boats and destroyers is obtained.

CAST IRON : WITH SPECIAL REFERENCE TO ENGINE CYLINDERS.*

BY J. EDGAR HURST.

THE trend of advance in connection with modern prime movers, particularly internal-combustion engines, would seem to be in the direction of the improvement of existing types rather than in the introduction of new types of engines. In this connection the materials of construction of the engines occupy no mean share of attention, and cast iron, of which the vitals, the cylinders and pistons of engines, are composed, is by no means of the least importance. The subject, "Cast Iron," has been dealt with many times before, by this and other institutions, and no doubt its importance in this connection is fully realised. It is an undoubted fact that grey cast iron possesses unique and invaluable properties when in use as rubbing parts, and this being the case one is surprised to find that much is still lacking in the way of actual scientific enquiry into the mechanism of the behaviour of cast iron in this respect.

One or two aspects of the application of cast iron to engine cylinder construction are of great importance, both from a metallurgical and engineering standpoint, and the study of these has engaged the author's attention for some time past. It must be borne in mind, however, that the subjects dealt with are by no means fully exhausted, and an enormous amount of work still remains to be done before these points are thoroughly elucidated and entirely understood.

The Wearing of Cast Iron.—The wearing and antifrictional properties of cast iron are very intimately related and undoubtedly interdependent; but for the sake of clearness and simplicity it will be advisable to consider them under separate headings. Wear for our purposes may be defined as the mutual loss in weight of two substances when rubbed together over a given period of time. Obviously when the number of substances with which, and the number of modes in which, cast iron can be rubbed, and so bring about wear, is considered, the subject becomes one of exceedingly wide dimensions. Therefore, for the purposes of this paper, it is proposed to consider only the case of wear such as occurs in engine cylinders, that is, wear brought about by the mutual rubbing or abrasion of cast iron by cast iron.

The supreme difficulty experienced in all cases of wear study is the lack of any satisfactory means of reducing industrial conditions to an experimental scale And doubtless it is to this cause that research in this direction has been so long delayed. Of necessity, therefore, we have to rely for our knowledge of the subject on that chiefly derived from investigations of actual industrial cases—a very slow and prolonged method.

The characteristic feature observed on the visual examination of worn gas engine liner surfaces is that the whole of the worn surface is covered to a more or less extent with small pits or holes. These holes or pits are commonly put down by many engineers to the coarseness of the grain of the cast iron, and are often considered to be the holes from which the coarse plates of free graphite existing in the original iron have been detached. This is not strictly correct, for as a matter of fact on microscopical examination of etched specimens these holes prove to be the result of the detachment of whole grains of any constituent from that particular portion of the surface of the liner. On subjecting worn liner surfaces to a microscopic examination one invariably finds the harder constituents standing in relief exactly as though the liner had been subjected to relief polishing.

Cast iron as a whole is a conglomerate of a number of constituents, ferrite, pearlite, cementite, and phosphide eutectic, of widely different mechanical and physical properties, the soft and ductile ferrite and pearlite on the one hand, and the extremely hard and brittle phosphide eutectic and cementite on the other hand. The whole of the grains constituting the mass are more or less separated by numerous graphite plates, resulting in the mass having a very low intercrystalline cohesion.

In the engine cylinder, under the influence of the abrading action of the piston rings, together with the slight initial surface disintegration, brought about by the stresses resulting from the reaction of the connecting rod, a certain amount of detached material is produced which becomes powdered and suspended in the film of oil. This suspended material, under the influence of the reciprocating motion of the piston, is undoubtedly responsible for the relief polishing of the surface of the cylinder, resulting in the harder constituents, usually the phosphide eutectic or the cementite, projecting above the surrounding material.

Eventually, these projections, together with the other grains composing the surface of the cylinder, under the influence of the abrading action of the piston rings and the vibratory stresses produced by the motion of the piston and the reaction of the connecting rod, are loosened and subsequently detached, a procedure which is no doubt facilitated by the increased temperatures and gas pressures inside the cylinder. Such is, in all probability, the mechanism of surface disintegration in engine cylinders.

Surface Flow Phenomena.—It has been well known to engineers for a long period that with cast iron parts which are subjected to the influence of rubbing actions, such as, for example, engine cylinders, slides, &c., immediately such parts have been in use for a sufficient length of time to have acquired a peculiarly glazed surface or glazed appearance, then satisfactory working of those parts is obtained.

The cylinder walls of high-speed engines, after having been in running for a considerable period, are harder, and become increasingly difficult to file, and the raised markings left on the cylinder walls after a "seizure" has taken place, are often glass hard and incapable of being filed.

The glazy appearance produced on cast iron liner surfaces after a period of running is undoubtedly very important, and plays a large part in the reduction of the extent of wear, and in the efficiency of its antifrictional properties. Our continental neighbours would appear to have realised this, and it is believed that some of the large continental gas engine manufacturers subject their gas engine liners and pistons to a period of running in the engine, previous to putting the engine in work. The object of this procedure is undoubtedly to bring about the production of this glazy appearance.

It is very probable that this glazy appearance is the product of a number of different causes. The most important one appears to be that under the influence of alternating stresses brought about by the motion of the piston, the surface grains are deformed by being broken down along the slip planes, ultimately producing a surface of very fine crystal structure. Micro-examination of such surfaces reveals in many instances very finely granular structures even at high magnifications. Such surfaces are harder, and will be obviously far less sensitive to the effects of surface disintegration than the original coarser grained structure. In addition, owing to the increase in the number of crystal boundaries, the total effect of intercrystalline cohesion is enormously increased, and whether this enhanced strength noted at the crystal boundaries is due to the influence of the presence of amorphous cement or surface tension, or both, such superficial layers on liners must be enormously strong. The presence of the elements manganese and chromium in notable quantity undoubtedly increases the resistance of cast iron to wear. This is due to the production of these deformed surface layers, which are readily produced in such irons. Micrographs taken of a gas engine liner surface after a seizure showed a layer of hard matter. The author considers that these layers consist of detached material which has been bodily deposited on the surface of the liner, either from the piston or displaced from some other portion of the liner. In all probability they consist of, in this instance, large ferrite areas which have been detached, and owing to their comparatively large size, and under the influence of the intense pressure, have "flowed" over the surface of the liner. It is very probable that the intense heat developed in this layer, owing to friction (which can actually be observed as a white heat), causes the rapid absorption of carbon either from the graphite or from the lubricant, or from both, resulting in the production, at this high temperature, of the hardenite solid solution. The cooling of this highly heated layer, in actual contact with the solid walls of the liner, is more or less rapid, and according to the degree of rapidity of the cooling, the type of structure and the degree of hardness presented by the layer is determined. On examination of these layers under the micro-

* Abstract of paper read before the Manchester Association of Engineers, December 9th, 1916.

scope, when etched, structures are revealed which are undoubtedly intermediate between hardenite and pearlite. Similar effects are sometimes obtained during grinding operations on cast iron. Under certain conditions when the wheel is said to glaze, in the case of cast iron this peculiar hard surface is produced. This is probably the result of surface flow in a like manner to that above.

Antifrictional Properties.—It is a well-known fact, that apart from the wear of metals and alloys under actual rubbing contact, that certain metals and alloys exhibit a special property of undergoing this rubbing treatment in a more satisfactory manner than others. The extent to which a metal or alloy will undergo this treatment without overheating or seizing, is to a large extent a property of the individual metal or alloy concerned, and this property for the purposes of this paper we designate its antifrictional property. It must be understood that the load, and possibly also the speed under which the mutual rubbing action takes place, also have an influence on this property. For our purposes these influences are at present ignored and considered as constant.

Reference to the so-called antifriction alloys affords an interesting analogy. These alloys are for the most part constituted of such metals as tin, lead, copper, and antimony, the proportions of which are so designed as to produce an alloy of such a character as to give the most satisfactory results from the point of view of overheating and seizure when in use as engine or line shaft bearings.

Experience has shown that such an alloy should as a general rule consist of at least two constituents of widely different physical properties embedded in each other. When in actual use the surface of such a metal becomes polished in relief, and the harder constituents project above the surrounding matrix, producing a surface of an irregular contour. It is considered that these hard projecting points serve as direct supports for the greater part of the load, whilst the minute hollows serve as minute reservoirs evenly distributing the oil over the whole surface.

In the high-speed engine cylinder the running properties of the material of which the piston and cylinder are constructed are subjects of great importance and demand wide recognition. Primarily it is owing to its special properties in this respect that engine cylinders are constructed of cast iron, and it is very significant that as yet we have no other material that will successfully replace cast iron in this capacity. In addition, the limitations of cast iron, both in respect of these properties and also the general mechanical strength properties, are a drawback to advance in high-speed engine design.

The general excellence of the antifrictional properties of cast iron is commonly ascribed to the lubricating qualities of the free carbon content. In a large measure this is quite true, though not *strictly* correct, and, indeed, when it is remembered that cylinder liners and pistons are in successful use for a number of years the influence of the superficial graphite content is not sufficient explanation.

Exactly as is the case with antifriction alloys previously mentioned, under the influence of the reciprocating motion of the piston, and the abrading action of the fine particles suspended in the oil, a surface of irregular contour is developed on the cast iron, the harder constituents standing in relief as illustrated in the section on wear. These minute hollows, together with the holes developed as a result of surface disintegration, serve as distributing reservoirs of the lubricant, ensuring efficacious and excellent distribution of the lubricant over the whole surface. It might also be mentioned at this point that the "glazy" surfaces presented by cast irons after subjection to continuous motion, are also an important consideration in this connection, although at present their influence is somewhat obscure.

Micro-Structure: Influence and Considerations.—It will readily be seen in this connection that the micro-structure of cast iron is of prime importance. In the first place it will be evident that up to a certain point, as a result of the wearing action on cast iron, a surface possessing good antifrictional properties is produced. Even in cast irons containing no well-defined hard constituents, such as say, for example, phosphide eutectic, the effect of surface disintegration will result in the production of surfaces having good antifrictional properties. Obviously, however, excessive wear as a means of obtaining efficient liner surfaces is highly undesirable from the point of view of engine power development, and in addition the excessive production of débris resulting from surface disintegration, more particularly in the initial stages of the running of liners, is a contributory cause to "galling or seizure."

The cast iron having the highest intercrystalline cohesion, otherwise the highest tensile strength, will possess the greatest resistance to surface disintegration, and, consequently, to wear. Under a given load and speed, therefore, it would appear that wear in engine cylinders is proportional to the tensile strength of the iron. This conclusion was arrived at by Messrs. Ludwig Loewe & Co., Ltd., from a series of experiments in which the wear was determined as the loss in weight after rubbing cast iron cylinders for a given length of time, under a given load and speed, on a hardened steel die.

Cast iron of the highest tensile strength at normal temperatures is that having the closest grained structure and a free carbon constituent existing in a very finely divided, or alternatively, in a rosette form.* Generally speaking, in so far as the tensile strength of cast iron is concerned, the identity of micro-constituents is of little importance providing the above conditions obtain. Consequently it would appear that the corollary of this statement is true, and that the identity of the constituents is of little moment in the case of wear.

In so far as pure surface disintegration is concerned, and under ideal conditions, this would appear to be perfectly true. The effect, however, of the action of alternating stresses on the character of the surface grains, and the effects of the differential polishing of these grains largely modify this conclusion, and in this respect the identity of the constituents is of importance.

It is yet too early to state definitely the influence of different constituents on the production of "glazy" surfaces. The greater portion of our knowledge and experimenting in this direction is confined to the behaviour of pure metals only, and its extension to, perhaps, the most complex of all alloys, cast iron, involves an enormous amount of work.

The extent of the differential polishing of the surface grains in a large measure depends upon the individual characteristics of the grains. It will be obvious that this effect in excess will rapidly lead to the inauguration of surface disintegration. Cast irons constituted of large grains, varying widely in physical hardness, are an example of this type of occurrence, and the comparatively rapid wearing of coarse-grained irons, consisting largely of ferrite and phosphide eutectic, is in a large measure due to this cause.

The influence of wear in the production surfaces of good antifrictional properties on cast iron has to a large extent been fully dealt with. The influence of the general micro-structural arrangement on one or two points is of importance. Photomicrographs obtained from polished and etched specimens of two samples of cast iron showed in one case a beautiful network arrangement of the phosphide eutectic and cementite, and in the other a blotched appearance, which, in this case, consisted of large ferrite areas, around which the hard constituent was indiscriminately distributed. A micro-structure of fairly large grain size is typical of a comparatively fast wearing liner, although at the same time possessing good antifrictional properties.

It must not be assumed that the presence of the hard constituent, structurally free, however, is absolutely indispensable for the production of a good wearing and running liner, and, in fact, cast irons of very low phosphorous content and containing practically no structurally free hard constituent, give excellent results in this respect. The study of the influence of pearlite in this respect is still under investigation in greater detail, and undoubtedly its influence is very important. Qualitatively it may be explained in part somewhat on the following lines. Pearlite consists of numerous very fine lamellæ of the two micro-constituents ferrite and cementite, which in individual properties represents the two extremes. The result of the polishing action on such a structure is the production of a surface containing very fine microscopic channels. Such channels behave in exactly a similar manner as fine capillary threads, distributing the lubricant undoubtedly by means of surface tension.

Hardness and Wear.—The lack of any means whereby the wearing properties of any material can be tested and readily adjudged is sorely felt by both engineers and metallurgists alike. It is customary to use the hardness number which is, as a general rule, obtained by the Brinell method

* Foster, Manchester Association of Engineers, January, 1904.

as a means of indicating the wearing properties of metals. As applied to cast iron for the purposes of engine cylinders, this method is far from satisfactory. Cast irons giving the same hardness numeral often wear at widely different rates, and furthermore, the influence of the presence of such elements as manganese and chromium which, in normal percentages, are not detected by the hardness numeral is most important.

The unsatisfactory nature of the Brinell hardness numeral in this capacity is undoubtedly due to a multiplicity of causes. In the first place, an enormous amount of uncertainty surrounds the definition of hardness, and it is very doubtful whether the methods of determining hardness actually do determine this property in its entirety. The hardness of a body, as defined by the nomenclature committee appointed by the Iron and Steel Institute, is "the resistance offered by a body to the 'mechanical' separation of its particles." It would appear from this definition that hardness and wear are very intimately associated. Indeed, it is the author's opinion that in a homogeneous material the true hardness property is its resistance to wear. From this, therefore, the resistance to wear is a function of the cohesion of the particles, or rather, in the light of more recent knowledge concerning the architecture of crystalline bodies, is the resistance to deformation, and it is therefore tentatively suggested that the yield point gives the more correct indication of the true hardness. The high resistance to wear of some of the non-ferrous alloys, *e.g.*, antifriction alloys, is in all probability due to their liability to produce under the influence of stresses during working overstrained superficial layers. The investigation of the yield point in this connection will doubtless throw much more light on this hitherto somewhat neglected subject.

To return to cast iron. It is extremely probable that wear due to surface disintegration is not exactly wear in the above sense, but is really a function of the brittleness of cast iron. The abrasion or relief polishing previously outlined is the true wear in that it depends upon the resistance to deformation of the individual component grains. The whole subject, particularly in reference to the material cast iron, it will be plainly evident, is extremely complex and involved, and an enormous amount of work still remains to be done.

The Brinell hardness test as applied to cast iron is most unsatisfactory, and it is practically impossible to correlate the figures obtained in this test with the chemical constitution of the cast iron. Broadly speaking, the hardness numeral varies with the combined carbon content. The presence of such hard constituents as phosphide eutectic increase the numeral. This can only be truly said of cast irons obtained under exactly identical conditions. In such a complex alloy as cast iron this is not at all surprising and is in all probability to be explained by the numerous subsidiary influences, chiefly the casting temperature, and the rate of cooling, which largely affect the structural arrangement and distribution and the grain size.

The impossibility of correlating the hardness numeral with other mechanical tests or the chemical constitution is doubtless largely due to the permanent bodily slip of the crystals under compression, owing to the presence of the free carbon constituent, and as a result it can only be considered that Brinell figures on cast iron are at all comparative when the conditions under which the specimens are obtained are strictly identical.

(*To be continued.*)

Restrictions on Manufacture and Sale of Aluminium.—The Minister of Munitions orders that the war material to which Regulation 30a of the Defence of the Realm (Consolidation) Regulations, 1914, applies shall include war material of the following classes and descriptions, namely: Aluminium and alloys of aluminium, unwrought and partly wrought, including ingots, notched bars, slabs, billets, bars, rods, tubes, wire, strand, cable, plates, sheets, circles, strip. Aluminium scrap and swarf, aluminium alloy scrap and swarf, remelted aluminium scrap and remelted aluminium alloy scrap and swarf. Granulated aluminium, aluminium powder, "bronze," "flake," and "flitter." The Order, dated July 21st, 1916, published in the "London Gazette" of July 28th, 1916, relating to aluminium and alloys of aluminium therein mentioned is hereby cancelled. All applications for a permit in connection with the above Order should be addressed to the Director of Materials, Ministry of Munitions, Armament Buildings, Whitehall Place, S.W.

FUEL ECONOMY AND LOCOMOTIVE BOILER DESIGN.*

BY J. T. ANTHONY.

THE importance of the subject of fuel economy is fully realised by all mechanical and operating officials. The many angles from which it can be approached and the numerous points that bear directly on it, are more or less familiar to all of you. Beginning with the specifications covering the purchase of the coal at the mines, we might enumerate: Inspection and loading at the mines, storage, weathering, handling at coal tipples, loading on tenders, firing instructions, water level and cut-off, lubrication, draughting and front-end arrangements, steam leaks, boiler washing, engine despatching, train loading, and terminal and other delays. Other factors which tend to increase the total fuel wasted might be mentioned and the sum of these would certainly amount to an appreciable percentage of the total coal purchased by the railroads.

It is doubtful, however, if the losses enumerated above will exceed the losses directly chargeable to the boiler—despite all efforts to increase the boiler economy and efficiency by the addition of such devices as the arch, superheater, feed-water heater, &c. To illustrate the losses that take place in the average locomotive boiler, we will take a typical boiler—such as is used on a medium size Pacific or Mikado engine. The boiler has a grate area of 54 sq. ft., 210 sq. ft. of firebox heating surface, 4,100 sq. ft. of fire tube and superheater heating surface (the tubes being 21ft. long and 2¼in. diam.), air opening through ashpan 20 per cent. of grate area, and air opening through grates 28 per cent.

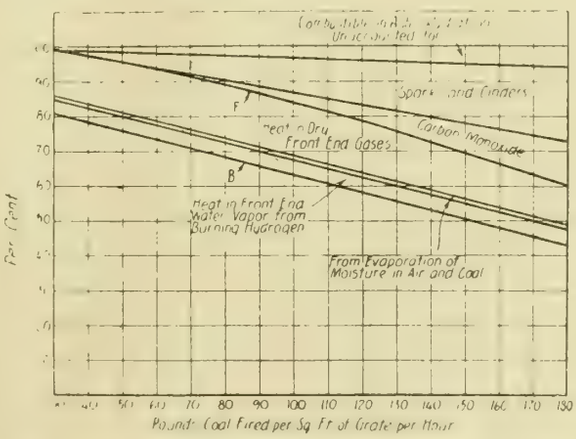


FIG. 1. HEAT LOSSES IN RELATION TO QUANTITY OF COAL FIRED.

The chart, Fig. 1, shows average heat losses as the rate of combustion increases from 30lbs. to 180lbs. per square foot of grate per hour. As might be expected, the results in individual tests varied widely; but the curve as drawn will approximate average results. The most striking losses are those due to sparks and cinders, which exceed 20 per cent. at the maximum rate; carbon monoxide and incomplete combustion, which exceed 13 per cent.; and heat in dry front-end gases, which in some cases reaches 16 per cent. In addition, there are comparatively small losses due to combustible in ash, radiation and unaccounted for, and heat losses in evaporating moisture in air and burning hydrogen in coal.

As shown by the line B, the over-all boiler efficiency drops from 80 per cent. at low rates of combustion down to 43 per cent. at the highest rate. In other words, when burning 30lbs. of coal per square foot of grate per hour, 80 per cent. of the heat contained in the coal is put into the steam; while at the maximum rate only 43 per cent. of the heat contained in the coal is transferred to the steam.

It is noted that the losses due to sparks and cinders and incomplete combustion increase rapidly as the rate of combustion increases; while the losses due to combustible in ash, radiation, and unaccounted for also increase. Under the same conditions, the losses due to burning hydrogen and evaporating moisture in the air remain almost constant, as does the loss due to heat in front-end gases. The sparks and cinders loss is due in part to the nature of the coal; but largely to the high draught necessary at high rates of combustion

* Paper read before the New England Railroad Club, October 10th, 1916.

and to the absence of efficient baffling and mixing devices and sufficient combustion chamber space. The losses due to carbon monoxide and incomplete combustion are due to the lack of sufficient oxygen at the high rates of combustion, and to lack of efficient mixing devices and combustion chamber space. The loss from combustible in ash is due partly to the nature of the coal, but largely to the design of the grate and method of firing.

Radiation loss for a well-lagged boiler is comparatively small, though difficult to determine with any degree of accuracy. The unaccounted-for loss is due principally to the escape of unburned hydrocarbon gases, which are not detected by the ordinary front-end gas analysis. The heat in dry front-

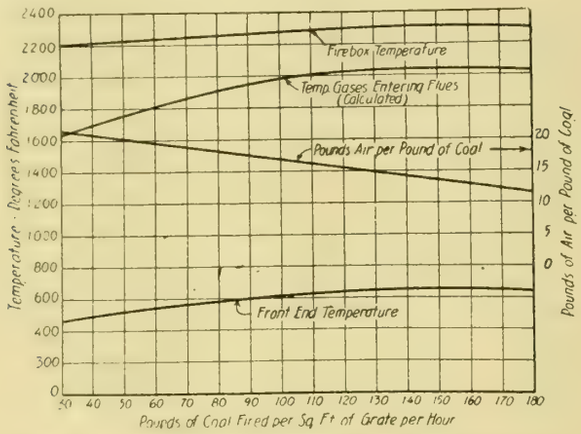


FIG. 2. VARIATIONS OF TEMPERATURES WITH RATE OF FIRING.

end gases is controlled by the temperature of the gases escaping at the front end and the amount of air used per pound of coal burned. These two factors also control the loss due to evaporating the moisture in the air, and heat loss due to the hydrogen of course depends upon the amount of hydrogen contained in the coal and the temperature of the escaping gases.

Chart, Fig. 2, shows the temperature of front-end gases, temperature of firebox, and pounds of air supplied per pound of coal, at the different rates of combustion. It is a difficult matter to get a regular curve showing the air supplied, on account of the wide variation in results given by the different gas analyses. This trouble is due not to any difficulty in making the gas analysis, but to the great difficulty of getting a fairly uniform sample of gas for analysis. All of the heat losses shown on chart Fig. 1 are chargeable to the boiler. Some of them are directly chargeable to the furnace (or firebox), while others are chargeable to the heating surfaces. If we ignore the radiation losses from the barrel of the boiler and assume that all the losses under this head are chargeable to the furnace, the sum of these losses—together with those due to sparks and cinders and incomplete combustion—will be the measure of the furnace efficiency.

This is shown in chart, Fig. 3, by curve 2—where the furnace efficiency is equal to the heat liberated divided by the heat in the coal. As shown, the heat loss due directly to the furnace varies from 2 per cent. to 40 per cent. of the entire heat in the coal; in other words, this much of the heat contained in the coal is not liberated in the firebox and is not made available for absorption by the heating surfaces. Curve 4, Fig. 3, shows the over-all boiler efficiency, which is measured by the ratio of heat absorbed to heat in the coal. The space between curves 2 and 4 represents heat liberated in the furnace but not absorbed by the heating surfaces. This amounts to from 18 per cent. to 20 per cent. of the heat contained in the coal, and of this large amount a relatively small proportion is available for absorption by the heating surfaces.

It is evident that the temperature of the gases flowing through the flues cannot possibly be reduced below the temperature of the water or steam in the boiler. With a boiler pressure of 200lbs., the steam temperature is 388°; and all the heat required to raise the products of combustion up to this temperature is unavailable for absorption by the heating surfaces and cannot be charged against them. As explained above, the amount of this unavailable heat depends principally upon the temperature of the front-end gases and the air supply per pound of coal. On the chart it is represented by the space between curves 2 and 3. The space between curves 3 and 4 represents the heat contained in dry front-end gases that is available for absorption but is not absorbed, and this heat can of course be directly charged against the boiler heating surfaces. Curve 3, then, shows the amount of heat available for absorption, and curve 4 shows the amount absorbed; and the ratio of heat absorbed to heat available becomes the measure of the heating surface efficiency. In other words, the percentages expressed by curve 4, divided by the percentages of curve 3, will give a figure which is a true indication of the heating surface efficiency.

This heating surface efficiency is shown by curve 1, which, it will be noted, ranges from about 98 per cent. to 88 per cent. at the highest rates, there being very little drop in the heating surface efficiency after the rate of combustion gets up to about 100lbs. of coal per square foot of grate. It was stated that curve 2 shows the true furnace efficiency, in that it represents the ratio of the heat liberated to the heat in the coal. Some authorities charge against the furnace all of the unavailable heat contained in the products of combustion, maintaining that it is the true function of the furnace to make all of the heat contained in the coal available for absorption by the boiler heating surfaces. In this case, curve 3 would become the furnace efficiency line. This seems hardly fair, as a large part of the heat contained in the gases (even with the theoretical minimum air supply) is unavailable for absorption and should not be charged against the furnace. Disregarding these technicalities, curve 1 will represent the efficiency of the heating surfaces; curve 2 will represent the efficiency of the firebox (or furnace), and curve 4 will represent the over-all efficiency of the boiler.

Having located and grouped the heat losses, thereby determining the efficiency of the heating surfaces and the furnace, the next problem is to determine the best method of reducing or eliminating these losses and increasing the efficiencies. As indicated in chart, Fig. 3, the losses directly chargeable to the furnace are far greater than those chargeable to the heating surfaces; and the firebox, therefore, seems to offer the largest field for future improvement. The loss due to sparks and cinders is due principally to the high draught necessary at the high rates of combustion. By reducing the rate of combustion, we can in a measure reduce this loss. Boiler capacity, however, is of prime importance, and we can-

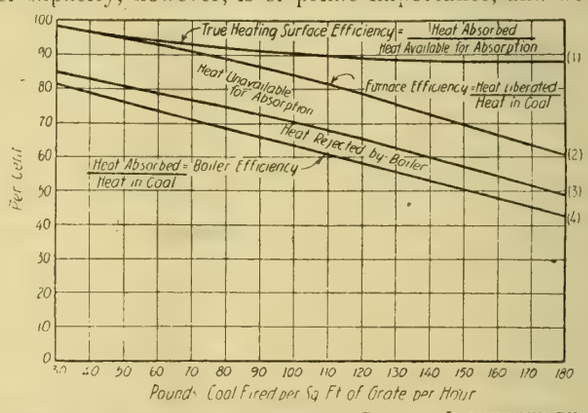


FIG. 3.—EFFICIENCY OF BOILER AND ITS PARTS AS INFLUENCED BY RATE OF FIRING.

not afford to reduce this capacity by reducing the amount of coal fired. It becomes necessary, then, to reduce the rate of combustion by increasing the grate area. This will enable us to carry a light fire; get a more uniform supply of air through the fuel bed; reduce the lifting action of the draught upon fine particles of coal; and, if accompanied by increase in firebox volume or combustion space and efficient baffling devices, will result in a material reduction in loss due to sparks and cinders, as well as those due to incomplete combustion and escape of carbon monoxide and unburned hydrocarbon gases. In order to burn coal completely, it is necessary to supply a sufficient amount of oxygen; to mix the oxygen with the combustibles of coal, and give them time to burn. Complete combustion cannot be obtained unless these requirements are met.

The effect of grate area upon evaporation is perhaps not well understood. Firebox heating surfaces take up practically all of their heat by radiation; that is, the heat travels from the luminous fuel bed, flames and brickwork by "rays" or "waves" to the firebox heating surfaces. The amount of

heat so received depends primarily upon the temperature of the radiating bodies and upon the area or extent of these radiating bodies, and not upon the extent of the firebox heating surfaces. The amount of radiant heat transferred is influenced to a small extent by the temperature of the firebox heating surfaces; but the effect of a slight increase in temperature here is insignificant as compared with an increase in temperature of the radiating surfaces, such as the fuel bed or the flames. When working at ordinary capacity, with clean sheets, it is possible that the temperature of the

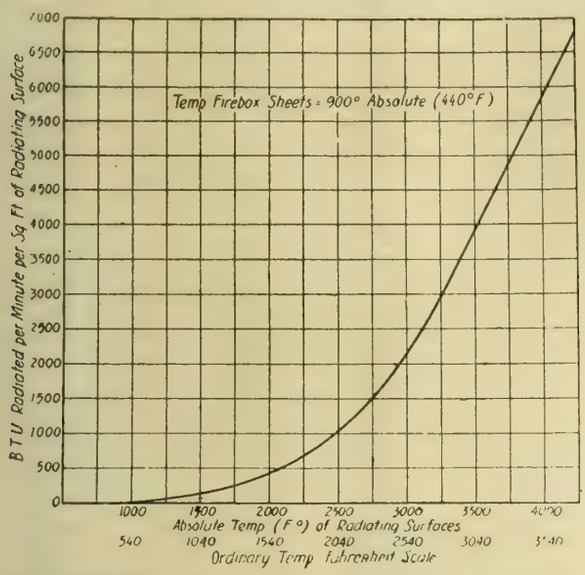


FIG. 4.—QUANTITY OF HEAT RADIATED IN RELATION TO TEMPERATURE OF FIREBOX.

fire side of the firebox sheets is about 440°. With this temperature of the firebox sheets, the amount of heat radiated by each square foot of radiating surface is shown by the curve in Fig. 4. From the chart, Fig. 4, it will be noted that a slight increase in temperature of the radiating surfaces gives a marked increase in the amount of heat radiated, and therefore in the amount of water evaporated. Increasing the firebox temperature from 2,040° to 2,540° doubles the amount of heat radiated from each square foot of radiating surface, and practically doubles the evaporation from the firebox heating surfaces. This shows the vital importance of high temperatures, both in fuel bed and flames, and is suggestive of the ill-effects that result from bank firing, or the placing of a lot of green coal in the firebox at one time. In order to get the maximum evaporation, it is necessary that the fuel bed be kept at a white-hot temperature all over. The bank of green coal reduces the effective heating surface, reduces the temperature of the firebox, and reduces the evaporation.

Accurate data on the question of firebox evaporation are difficult to get, as no conclusive tests have ever been made. Using the available data as a basis, however, there have been platted the curves in Fig. 5, showing the possible firebox evaporation and tube evaporation. The top curve shows the actual equivalent evaporation from the boiler at the varying rates of combustion. The firebox evaporation was calculated, and the tube evaporation is, of course, the difference between the firebox and the total. The firebox evaporation was calculated by using the firebox temperatures shown on chart, Fig. 2, and adding the heat radiated by the flames to that radiated from the fuel bed, assuming in all cases that the temperatures of the flames and of the fuel bed were the same and that the average temperature was that shown by the curve, chart, Fig. 2.

The coal used in the particular tests from which data for these curves were derived contained about 35 per cent. volatile, with a heat value of 14,500 B.T.U. per pound. With a coal of this volatile content, the firebox will be completely filled with flame at moderate or high rates of combustion. If the firebox is completely filled with flame, the effective flame radiating surfaces will be equal to the exposed firebox heating surfaces. The firebox in question had a heating surface of 210 sq. ft. Assuming that the fuel bed covered the side sheets to a depth of 1ft., we would have 180 sq. ft. exposed to the action of the flame; and if the firebox is completely filled with flame, we could safely assume that we would have 180 sq. ft. of effective flame-radiating surface. At low rates of combustion, the amount of volatile combustible driven off would not be sufficient to completely fill the firebox with flame; and it is probable that at very low rates (around 30lbs. or 40lbs. per square foot of grate), the firebox would only be about half filled with flame.

This assumption was taken in making the calculations, with results shown by the curves in chart, Fig. 5. As indicated by the curves, the firebox evaporated nearly one half of the total at low rates, and about one third at the highest rate. The maximum calculated evaporation from the firebox was 21,000lbs. per hour, or an equivalent evaporation of practically 100lbs. of water per square foot of heating surface. To secure such evaporation, it would be necessary to have a temperature drop of 140° between the fire side and the water side of the sheets, assuming that we use sheets ⅜in. thick, free from scale, which would give a fire side temperature of 528°, and which is probably well within safe working limits. Under the same conditions, the maximum evaporation from the tube heating surfaces (including superheater) would be 10lbs. per square foot per hour; or, the firebox would be evaporating ten times as much as the tubes per square foot of surface. An equivalent evaporation of 100lbs. of water per square foot of firebox heating surface per hour seems abnormally high, but there is no logical reason why such evaporation should not be obtained. It is merely a question of getting enough radiating surface at a sufficiently high temperature.

Increasing the grate area increases the area of the fuel bed radiating surfaces, and increasing the firebox volume or combustion chamber space increases the flame-radiating surfaces. Increasing the grate area also means low rates of combustion, more uniform air supply, lighter fire, reduction in losses due to unburned fuel, an increase in the percentage of heat liberated, and an increase in firebox efficiency, both as a furnace or heat-liberator and as a heat-absorber. It is possible that the value of combustion chamber space is not fully realised, for the large number of engines now being built with abnormally long boilers and flues offers opportunities for combustion chamber installations of which advantage is not being taken.

Bituminous coal is not a homogeneous substance. It burns partly as a solid and partly as a gas. The solid part burns on the grate in the form of fixed carbon, while the volatile

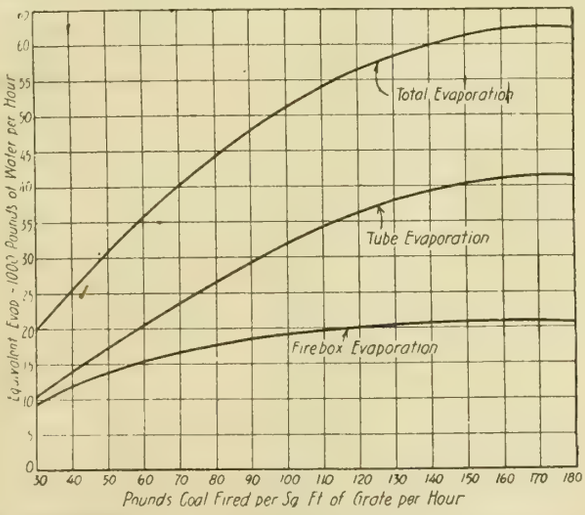


FIG. 5.—DISTRIBUTION OF EVAPORATION AS AFFECTED BY RATE OF FIRING.

burns in the combustion chamber space as a gas. The coal used in the test under consideration contained 58 per cent. fixed carbon and 26 per cent. volatile combustible. Therefore 1lb. of the coal contained ·58lb. of carbon, which, burned on the grate, liberates 8,500 B.T.U., and ·26lb. volatile combustible, which, burned in the combustion chamber space, liberates 6,000 B.T.U. Thus we see that more than 40 per cent. of the heat is liberated by burning gas in the combustion chamber space, considering that all the fixed carbon burns on the grate. In actual practice, however, the fixed carbon is not completely burned on the grate. The oxygen, on coming in contact with the hot coal near the grates, combines with the carbon to form carbon dioxide; and this carbon dioxide, passing up through the hot fuel bed, takes up more carbon and is partly reduced to carbon monoxide.

After leaving the fuel bed, this carbon monoxide is burned in the combustion chamber space and again forms carbon dioxide; provided, of course, that sufficient oxygen is present and proper mixing is accomplished. The amount of carbon monoxide formed in the fuel bed depends upon the temperature of the fuel bed and its thickness.

Gas samples taken just above the fuel bed in stationary furnaces indicate that a large percentage of the fixed carbon is incompletely burned to carbon monoxide in the fuel bed. While there are no data available as to the exact percentage of carbon monoxide formed in the fuel bed of a locomotive, considering the temperatures and thickness of the fire generally carried, it is not unreasonable to suppose that the fuel bed acts principally as a gas producer and that at least four-fifths of the carbon is incompletely burned on the grate. The combustion of the carbon monoxide so formed is completed above the grate in the combustion chamber space. If this condition does exist, every pound of coal burned liberates 3,750 B.T.U. in the fuel bed and 10,750 B.T.U. in the combustion chamber space above the fuel bed. In other words, 26 per cent. of the combustible is completely burned on the grate, and 74 per cent. is burned above the grate. While these figures may not be strictly accurate, they serve to show the importance of ample combustion chamber space, and of the presence of free oxygen or air above the fuel bed.

With a firebox temperature of 2,300°, every pound of coal burned produces 1,188 cub. ft. of gas. Of this large amount, 78 cub. ft. is carbon monoxide, which is combustible, and 17 cub. ft. is a rich hydrocarbon gas, the average composition of which may be taken as ethane (C_2H_6). Mixed with these combustible gases are 20 cub. ft. of carbon dioxide, 174 cub. ft. of free oxygen, and 890 cub. ft. of inert nitrogen, together with traces of sulphur dioxide and water vapour; or, 95 cub. ft. of combustible gases mixed with 174 cub. ft. of free oxygen and more than 900 cub. ft. of inert gases. To put it in another way: For every molecule of combustible gases there are present less than two molecules of oxygen, which are mixed with 10 molecules of inert gases. These inert gases interfere with the meeting of the combustible gases with the oxygen and tend to retard combustion. The light combustible gases are not difficult to burn if supplied and intimately mixed with the necessary amount of oxygen and given time to burn; but the relatively small amount of oxygen present is mixed with such a large amount of inert gas that the probability of the combustible gas coming in contact with the oxygen within the very limited time available is greatly reduced. The heavy hydrocarbons are driven off in a semi-fluid or pasty condition, sometimes in the form of small globules of tar, which are very difficult to burn and which for the most part escape unburned. The heat loss due to this source can be reduced only by the use of efficient mixing devices and the provision of long combustion chambers and ample air supply above the fuel bed.

There has been mentioned the time required for combustion of the volatile hydrocarbons. The analysis of the fuel used in the test showed that every pound of coal produced 1,188 cub. ft. of gas at a firebox temperature of 2,300°. When burning coal at the rate of 100lbs. per square foot of grate per hour, there is produced 1,780 cub. ft. of gas per second. The volume of the firebox in question is 250 cub. ft., so this firebox must discharge and be refilled with gas more than seven times per second; or, the time available for the combustion of each particle of gas is less than one-seventh of a second. As the rate of combustion decreases, this time increases; and as the rate of combustion increases, this time available decreases. It is very apparent, however, that by increasing the firebox volume and the combustion chamber space, we increase the time available for the combustion of the volatile matter. We see, therefore, that combustion chamber space is valuable both as a means of increasing the efficiency of combustion and also as a means of increasing the radiating surfaces and firebox evaporation; and as we increase either of these, we increase the over-all efficiency of the boiler.

The curves in chart, Fig. 6, show the amount of heat absorbed by the firebox and tube surfaces, and the efficiency of the entire heating surfaces as compared with the tube heating surfaces. It will be noted that at low rates of combustion the tubes absorb from 90 per cent. to 94 per cent. of the heat available, while at high rates they absorb about 83 per cent of the heat available. In other words, as we increase the amount of heat to be absorbed by the tubes we decrease their efficiency. It will be noted that the efficiency line of tube heating surfaces almost parallels that showing the heat absorbed by the firebox. As the percentage of total heat absorbed by the firebox decreases, the percentage of heat to be absorbed by the tubes increases, and the tube efficiency decreases. It will appear from this that if, under any given set of conditions, we can increase the firebox evaporation, the efficiency of the tubes and the over-all efficiency of the boiler will be increased. The firebox heating surfaces have an efficiency of, we might say, 100 per cent.; that is, these surfaces will absorb practically all of the heat that is available, and by "available heat" in this case we mean the radiant heat. The firebox heating surfaces absorb but very little heat by convection from the hot gases, and the heat contained in the hot gases cannot be considered as available for the firebox heating surfaces. By increasing the amount of heat given off by radiation, we decrease the amount of work to be done by the tubes.

Flues take up heat by convection; that is, by actual contact of the hot gases against the flue-heating surfaces. The amount of heat so received depends upon the temperature, density, and velocity of the gases passing through. As we increase the rate of combustion, we increase the weight of

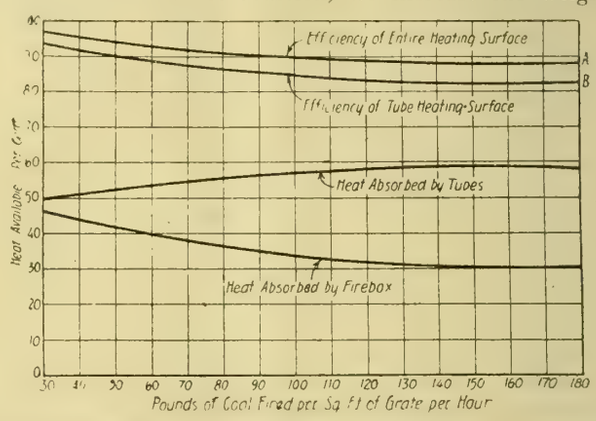


FIG. 6—ABSORBING CAPACITY AND EFFICIENCY OF FIREBOX AND TUBE HEATING SURFACE IN RELATION TO RATE OF FIRING.

volume of the gases and therefore the velocity. At the same time there is an increase in the temperature and a decrease in the density. In order to get heat out of the gases into the flue-heating surfaces, it is necessary to bring the small particles of gas into actual contact with the heating surfaces. To do this successfully, it is necessary to break up the gas into small streams by the use of small flues. As the gases pass through the flues, the molecules are vibrating rapidly in all directions and are striking against the heating surfaces, giving up their heat. The amount of heat given off will depend not only upon the temperature of the particles of gas, but also upon the number of blows they strike against the heating surfaces. This depends partly on the density, which controls the number of molecules in a given volume of gas, but largely on the diameter of the tube.

A decrease in the diameter of the tube decreases the average distance of each particle of gas from the heating surfaces. Each particle will therefore have a smaller distance to travel in order to strike the heating surfaces; and in passing through a flue of given length, it will come in contact with the surfaces oftener and will give up more heat, resulting in a lower front-end temperature and higher boiler efficiency. The efficiency of a tube increases as the diameter decreases and as the length increases, though tests seem to indicate that tube lengths in excess of 100 or 110 times the internal diameter are not productive of high capacity or efficiency. In other words, the tube-heating surface gained by increasing the length above 110 times the internal diameter is of little benefit in reducing front-end temperatures and in increasing the boiler capacity. It would seem, then, that any improvement in the efficiency of tube-heating surfaces must be brought about by decreasing the diameter of the tubes, or by decreasing the amount of work to be done by the tubes.

As was indicated by the chart, Fig. 6, increasing the percentage of heat absorbed by the firebox reduces the percentage of heat to be absorbed by the flues and increases the flue

efficiency. This increase in firebox heat absorption can be obtained by increasing the grate area, combustion chamber space, and, necessarily, the firebox heating surfaces. The use of larger fireboxes and longer combustion chambers would enable us to reduce the present excessive length of flues, and possibly to increase their efficiency, by a reduction in the diameter. The present troubles on account of tubes plugging and filling up are not due to the size of the tubes uesd, but are due entirely to the incomplete burning of the fuel in the firebox. If the present furnace conditions can be remedied to the extent that approximately perfect combustion can be obtained, there is no logical reason why a tube smaller in diameter and shorter in length cannot be used effectively; but such tubes can be used only in conjunction with a firebox containing large grates, efficient baffling and gas-mixing devices, large volume and long flame-way or combustion chamber space.

A comparatively small percentage of the engines in service to-day are equipped with combustion chambers, although this deficiency has been partly overcome on more than 30,000 locomotives by the installation of the brick arch. What has been said about the value of radiating surfaces, high firebox temperatures, complete mixing and baffling of the gases, and combustion chamber space, is sufficient to explain the benefits derived from the arch and to account for its almost universal use. By causing all the flames to pass around and over it, the arch completely fills the firebox with the burning gases or flames, and thereby increases the radiating surfaces as well as the temperature in the combustion chamber formed above the arch. The value of this device is thoroughly recognised. While it has done much to reduce fuel losses and increase locomotive efficiency, it cannot overcome all of the deficiencies of firebox or boiler design. It will increase the efficiency of a firebox limited in grate area or volume, but the maximum firebox efficiency cannot be obtained by the use of the arch alone. Large grates with medium rates of combustion and long combustion chambers are necessary, and, when used in conjunction with the arch, will add materially to both the capacity and efficiency of the locomotive boiler.

To summarise briefly: (1) The capacity and efficiency of the locomotive boiler seem to be limited by the inability of the firebox to properly burn the coal and liberate the heat contained. (2) The larger part of the heat losses (particularly at high rates of combustion) are due directly to the inefficiency of the furnace. (3) The second largest heat loss is that due to the heat escaping in the front end gases, which is unavailable for absorption by the boiler. (4) The amount of heat rejected by the heating surfaces is comparatively small, and the heating surface efficiencies are high, as compared with the furnace efficiency. (5) The efficiency of the furnace can be increased by increasing the grate area and reducing the rate of combustion, by providing effective baffles and gas mixers, and by increasing the firebox volume by making the fireboxes as deep as possible and equipping them with long combustion chambers. (6) The front end heat loss will be reduced as the efficiency of the furnace is increased; but there will always remain a large portion of unavailable heat, which can only be utilised by means of some auxiliary apparatus, preferably a device for pre-heating the air used in the furnace. (7) The efficiency of the heating surfaces can be increased by increasing the radiating surfaces. This will result in a higher firebox evaporation and reduction in the amount of heat to be absorbed by the flues, which in turn would mean higher flue efficiency. (8) Increasing the size of firebox and length of combustion chamber necessarily means shortening the flues. If the flues are reduced in length to less than 110 times the diameter, the decrease in efficiency will be largely offset by the increase in heat absorption by the larger firebox, and can be more than offset by decreasing the diameter of the flue to correspond with the decrease in length. (9) The vital part of the boiler is the firebox. It liberates and makes available the heat energy stored in the coal. A considerable portion of this energy is now being wasted through the inability of the firebox to properly burn the coal. The highest degree of fuel economy cannot be obtained while this condition exists. Future developments in firebox design along the lines suggested should result in a still further reduction of the coal bill and an increase in the steaming qualities and efficiency of the locomotive.

THE PROPORTIONING OF SURFACE CONDENSERS.*

BY GEORGE A. ORROK

DURING the discussion of my paper on "The Transmission of Heat in Surface Condensation,"† I was asked to present formulæ covering the application of the results of my experiments to the design of surface condensing apparatus. Since the appearance of the paper there have been a number of papers on allied subjects whose authors have approached the subject from a somewhat different standpoint, and the conclusions presented have been of varying character and usefulness in the design of surface-condensing apparatus. Only one author, Loeb, has presented new experimental data which can be used for checking the heat-transfer constants, but considerable mathematical work has been done along the line of following out Jordan's deductions from Osborne Reynolds's statement of the law of heat transfer. I propose in this paper to discuss the state of the art of "heat transfer in surface condensation," and to establish design formulæ for use in proportioning condensing apparatus.

The Probable Law of Temperature Rise.—The law of temperature rise of the water in a condenser tube is still unknown. My own tests led me to believe that this law departed somewhat from the logarithmic law as stated by Smith and Josse, but their results are sufficiently variant to allow for a slight modification. Loeb, however, has presented a set of tests with plotted curves, from which he deduces that the law is of the exponential form, with approximately 0·9 as the exponent. My plotting of his numbers places the exponent nearer 0·8, both of which are not far from my adopted figure of 0·875. These variations are not of prime importance for practical design, and indeed may be caused by the apparatus used in the making of the experiments; and I am still of the opinion that we may use $N = K\theta^{0.875}$ as the basis of our work, N being the total heat transfer per square foot per hour in B.T.U., θ the temperature difference, and K a constant determined by experiment.

Viscosity not an Important Factor in Design.—It has been stated in "Engineering" (January, 1914) that the extreme variation in the results of heat-transfer experiments has been caused by a neglect of the variation due to the viscosity of the water, and quite an extended argument was given to show that some of these experiments were reconciled when the correction was applied. Wilson has carried this method to its logical conclusion in his paper, "A Basis for Rational Design of Heat-Transfer Apparatus," lately presented to the Society. Our work in the design of surface condensers, however, is mainly concerned with a very small variation in temperature, the upper limit of which is fixed by the vacuum carried at somewhere between 80° and 90° Fah., while the lower limit in America is between 65° and 70°, and in Europe perhaps a few degrees lower—in all a variation of perhaps 20°. In the winter we can carry good vacuums with low heat transfer and our troubles are few, but the problem is the summer problem, and here the difference in viscosity is small. As a matter of fact, I believe Osborne-Reynolds's straight-line law does not apply where there is a change of state at either side of the metallic surface. Observers making use of this hypothesis have been frequently misled by the bunching of the results in the condenser range, with the consequent spreading of the results outside this range.

Critical Velocities Need Not be Considered. There has been considerable comment on the effect of stream flow and turbulent flow on the heat transmission, and as there is a marked change in the friction characteristics between the two states of flow, the conclusion has been drawn that there will be a similar effect on the heat-transmission characteristics. Osborne-Reynolds investigated this subject and gave formulæ for the critical velocities. He finds two critical velocities, the lower, which we may call V_l, below which all motion is stream line and if disturbed artificially will return to stream-line flow; and an upper critical velocity, V_u, above which all

* Abstract of paper read at the annual meeting of the American Society of Mechanical Engineers, December 5th to 8th, 1916.

† Reproduced in the *Mechanical Engineer*, December 9th, 1916. See page 757, Vol. XXVI.

motion is turbulent. Between the two is a field in which stream-line motion may be maintained if no artificial causes upset it, or turbulency may be set up and will maintain itself when so started. He gives formulæ for these two velocities, which, following Parker, are

$$V_c = \frac{0{\cdot}0388\,P}{D} \text{ and } V_a = \frac{0{\cdot}2458\,P}{D}$$

where D is the internal diameter of the tube in feet and P is Poisseuille's ratio, *i.e.*, the ratio between the viscosity and density of the water. If the values of μ = viscosity and δ = density be taken in C.G.S. units,

$$P = 56{\cdot}2\,\frac{\mu}{\delta}\begin{cases} = 1{\cdot}000 \text{ at } 0^\circ \text{ cent. } (32^\circ \text{ fah.}) \\ = 0{\cdot}734 \text{ at } 10^\circ \text{ cent. } (50^\circ \text{ fah.}) \\ = 0{\cdot}455 \text{ at } 30^\circ \text{ cent. } (86^\circ \text{ fah.}) \end{cases}$$

This agrees with Osborne-Reynolds's value, which is

$$P = \frac{1}{1 + 0{\cdot}0336\,T + 0{\cdot}000221\,T^2}$$

where T is the temperature in centigrade degrees. The table of correction factors in Wilson's paper may be used as a table of P by multiplying the correction factors by 0·625, thus correcting the values to 32° Fah. The critical velocities for a 1in. No. 18 B.W.G. condenser tube will then be as follows, T being the mean temperature of the water:—

T deg. fah.	40	50	60	70	80	90	100	115	130	150
V_c ...	0·50	0·422	0·362	0·318	0·278	0·25	0·224	0·192	0·166	0·14
V_a ...	2·84	2·400	2·060	1·810	1·580	1·42	1·270	1·090	0·945	0·80

In condenser practice and in most of the apparatus for heat-transfer experiments it is nearly certain that the flow is turbulent above V_c. Velocities from 6ft. to 10ft. per second are the common range in modern surface condensers, so that in every practical case the critical velocity need not be considered.

Conditions Determining the Value of the Co-efficient K.—Surface-condensing apparatus is never tested to the capacity of the surface to transfer heat, and Gibson and Bancel have shown this in their characterising the "active" and "inactive" zones in a surface condenser. The condenser must be designed for the maximum load that may be put on it when the entering water is at its maximum temperature, and additional surface must be installed as a factor of safety against dirty, oxidised tubes and the presence of undue amounts of air. The depression of the hot-well temperature below the vacuum temperature, a well-marked phenomenon in many condensers, may be eliminated by good design, and many tests by careful investigators have been reported in which the depression was zero. Certain designs of the dry-tube type may give hot-well temperatures somewhat higher than the average temperature in the condenser. The hot-well depression is especially marked where drowned lower tubes are used.

Neilson and others have objected to conclusion (*b*) in my 1910 paper that the heat transmission is approximately proportional to the square root of the cooling-water velocity. Within the condenser range the experiments may perhaps be better represented by $KV_w^{0{\cdot}6}$ instead of $KV_w^{0{\cdot}5}$. Weir (Trans. I.E.S.S.), in his paper read October 22nd, 1912, gives a curve for the relation of U to V_w for design purposes. The curve corresponds very closely to $U = 250\,V_w^{0{\cdot}6}$, the maximum variation being less than 2 per cent. It is possible that a closer agreement might be secured by using more figures in the exponent, but such a procedure is hardly necessary, as probably we have already exceeded the accuracy of our experimental apparatus. The effect of air in reducing heat transmission has been shown in my 1912 paper, and a term introducing the second power of the pressure ratios recommended to allow for it in design. This subject is still unsettled and will remain so until Smith's experiments are repeated on a proper scale, with known amounts of air present in the condenser. We may say that the term $(P_s/P_t)^2$ represents the reduction of heat transmission by air, with a possible variation of 10 per cent. The difficulty is in obtaining a figure for the amount of air present and its temperature. The use of the air bell enables the operating man to keep his leakage down to the minimum, and where water-jet air pumps are used the addition of the testing dry vacuum pump and air bell will usually pay for themselves in a very short time.

The attempt to find a better tube material than Admiralty brass has failed, and the standard tube to-day is a heat-treated Admiralty-mixture tube whose material coefficient is 0·98. This coefficient can now be neglected. A number of experiments with dirty and oxidised tubes have been made, but since it is possible to clean a tube by mechanical means and secure the original heat transmission, the cleanliness coefficient may be also neglected in design and only used in checking up a condenser test where allowance must be made for a dirty tube condition.

Assuming that I had practically air-free steam in the experimental apparatus and clean tubes, the value of K is $U\theta^{0{\cdot}125}/V_w^{0{\cdot}6} = 470$. The value 630 given in my paper was arrived at by assuming an air pressure of about 0·065in. of mercury. If the air-term influence be taken to the second power, $K = 570$. In both cases 90 per cent. cleanliness and 0·98 for material were assumed.

We know that the results of single-tube experiments may be approached in real condensers, and the closer the approach when the condenser is supplied with sufficient steam the better the performance of the condenser. We know that they never can be approached with light loads or with colder water, because only so much heat is transferred as is present. This definitely prevents the use of Jordan's "mass flow" formulæ or the electric resistance simile. These hypotheses can only be true where no change of state takes place, and this condition is entirely foreign to heat transfer as met with in condenser practice.

We may now put down the following principles:—

(*a*) The law of temperature rise in the tube is of the exponential form, with $0{\cdot}875 = \frac{7}{8}$ (0·9 or 0·8, perhaps) as the exponent.

(*b*) We may neglect viscosity for design purposes in America where the water temperature is 65° to 70° Fah., and the vacuum 28in. and over.

(*c*) We may also neglect critical velocity, since all condenser velocities are far above it.

(*d*) For velocities in condenser practice we may take K as varying as the 0·6 power of the velocity.

(*e*) The reduction in heat transmissive power due to air is very approximately covered by the use of a term $(P_s/P_t)^2$ as a reducing factor of K.

(*f*) For design work we may reduce the value of K once for all to account for the cleanliness of the tube and the material itself.

(*g*) The value of K will then be reduced to somewhere between 300 and 400 for design purposes, say 325 for average good working.

The Author's Method.—Condenser specifications usually call for the condensation of a certain amount of steam per hour, W (lb.), and the maintenance of a vacuum referred to standard barometer or absolute pressure P_v, with condensing water at a certain temperature, t_o. The quantity of condensing water, Q, the hot-well temperature, t_s, the power used by the auxiliaries and the steam consumption of the auxiliaries may be also specified, but the problem is reasonably determinate when W, P_v, and t_o are known. It is important that the place of measurement of the vacuum P_v be specified, as there is a well-defined drop through most condensers, the vacuum being greatest at the air-pump suction, less in the condenser, and least at the prime-mover nozzle. This drop may amount in well-designed condensers to 0·2in. of mercury. The specified vacuum should be measured at the prime-mover nozzle, and the designer, according to his judgment, will then allow 0·1in. to 0·2in. for the drop in the condenser.

The absolute pressure in the condenser will then be 29·92—(vacuum + 0·2in.) = P_v. The steam tables may now be consulted and t_s the temperature corresponding to the vacuum, λ = the total heat and q = the heat of the liquid be taken therefrom. The final temperature of the condensing water approaches t_s, and for close work may be $t_1 = t_s - 5^\circ$. In ordinary practice, $t_1 = t_s - 7^\circ$, or in some cases 8° or 10°. The ratio of condensing water to steam condensed, which is $R = \frac{\lambda - q}{t_1 - t_o}$, may next be found. Many designers consider it close enough to use 1,000 for $\lambda - q$, on account of the moisture in the exhaust steam, and some few use 968. I prefer to use

k q not on account of its accuracy, but as a slight factor of safety. Q, the quantity of condensing water $W R$ in lb. per hour.

At this point the size and thickness of the condenser tubes as well as the water velocity must be chosen. Some large installations use 1in. tubes on account of bad water conditions, although it has been stated that smaller tubes are more efficient (*vide* Weighton, Neilson, and Weir). There are no definite experiments to decide this point, although from Loeb's work on $\frac{3}{4}$in. tubes we may deduce a value of K 600 against K 470 for my experiments on a 1in. tube. Nevertheless, it is doubtful if anything is saved by the use of anything smaller than $\frac{3}{4}$in. when the pumping head is considered. $1\frac{1}{4}$in. tubes have also been used, but the consensus of opinion seems to be that a 1in. tube can be cleaned better, keeps in good condition longer, and can be made better than either smaller or larger tubes. Let us take 1in. tubes, No. 18 B.W.G., as standard. The formulæ may readily be altered for other sizes of tubes when the constants are known. With 1in. tubes velocities from 7ft. to 10ft. per second are now usual. We may take 8ft. per second as the standard value for V_w.

The number of 1in. tubes in one pass will be given by the formula

$$n = \frac{Q}{990\ V_w}.$$

The length of water travel (l), or the total tube length, may be found from

$$l = \frac{30{\cdot}8\ Q}{325\ V_w^{0{\cdot}6}\ n}\left[\ (t_s - t_0)^{0{\cdot}125} \quad (t_s \quad t_1)^{0{\cdot}125}\right]$$

and the total tube surface S from

$$S = 0{\cdot}262\ nl.$$

With 1in. tubes from 40 to 80 will occupy 1 sq. ft. of tube-plate area, depending on the spacing and general design. The average will be about 60, making the cross-sectional area of the condenser (square feet) equal to ($n \times$ number of passes) $\div$ 60. If there are two passes the length of the condenser will be $L = \frac{1}{2}l +$ depth of water boxes.

Best Tube Lengths and Temperature Rises.—The paper here gives the condenser formulæ proposed by Neilson in his paper read before the Institution of Engineers and Shipbuilders of Scotland, together with those published in Morrow's "Steam Turbine Design," and in Bauer and Lasche's "Marine Steam Turbines." These writers use the arithmetical mean for the mean temperature difference. Neilson says: "Equations for θ_m involving the use of hyperbolic logarithms are not to be recommended for condenser design," the reason being that the steam-air mixture in the condenser is not homogeneous. Weighton, upon whose experiments Morrow's work is largely founded, did not consider θ at all in his paper. Many other authorities follow this rule also, and I must acknowledge this position to be correct providing that equal increments in the temperature rise of the water in the condenser tube accompany equal increments of length. The tests of Smith and Josse, as well as my own, have definitely proved that this is not so. Thermometers placed in the water boxes of any two or three-pass condenser will also show this fact very plainly.

Now for each curve of temperature rise except the arithmetic there is a definite relation of l/d which is best for any given condition. Under the arithmetical law any values of d, n, and l which will give the necessary surface should be equally efficient, and 10 tubes 100ft. long should work as well as 1,000 tubes 1ft. long from the heat-transfer standpoint.

The differences between the logarithmic law and the exponential with an exponent between 0·9 and 0·8 are quite small, but the length of the tube required by the formulæ is considerably shorter using the logarithmic formula.

Taking the steam temperature t at 90°, the entrance water temperature t_0 at 70°, and the discharge at 80°, with a water velocity of 8ft. per second and 1in. tubes, I figure the best tube lengths and temperature rises as follows:—

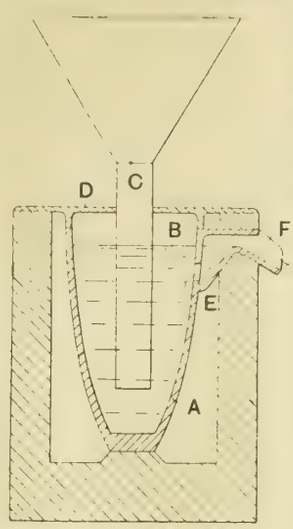
	Tube Length, Ft.	Rise in Deg. Fah.
Arithmetical law	23·2	0·4310° per foot of tube
Logarithmic law	24·0	0·4918° in first foot
Exponential law (exponent = 0·875)	26·8	0·5624° in first foot

It is to be hoped that some investigator will definitely settle this question on which so much in condenser design depends.

The paper gives a logarithmic chart for the ready determination of such fractional and decimal powers of numbers as are called for by the formulæ given.

METAL-MELTING FURNACE.

WE illustrate herewith a design of furnace for melting metals, particularly brass, gun-metal, or other metal turnings, the joint invention of Mr. H. N. Davis and Mr. W. R. Twigg, of the Diamond Foundry, Luton, Beds. The metal to be melted is inserted into the crucible A at a point below the surface B of the molten metal already therein. For this purpose a tube C of fire-clay is inserted into the furnace, its lower end being below the working level of the metal therein. Through this tube the metal to be melted is introduced, either continuously or intermittently, and by gravity or by any suitable mechanical appliances. The molten metal is drawn from the furnace by simple overflow through the orifice E and spout F by siphonage from the bottom or through a tapping hole, and provision is made for removing the dross formed so that the melting operation may be carried on continuously if desired. Access to the top of the crucible is obtainable by means of the removable lid D, which is made in sections so as to surround the tube C, and which rest, as shown, on the upper edge of the crucible and on the top of the furnace walls. The tube C is provided with a feed hopper, as shown.



METAL-MELTING FURNACE.

USE OF STEAM FOR MELTING SOFT METALS.

AN American firm using large quantities of type metal are using steam successfully for melting purposes. The metal, an alloy of lead and antimony, is used for setting bearings and the like in cored castings. The alloy has a melting point of 475° Fah., and it is essential that it be poured at a temperature not exceeding 550° Fah. Ordinary gas-heating melting furnaces such as are in common use for this kind of work necessitate the constant vigilance of an attendant using a thermometer in order to prevent overheating of the metal bath. It was thought that by means of a coil containing steam at sufficiently high pressure the latter being kept constant automatically, the metal bath could be kept in proper condition, ready to be drawn from without an attendant. The pressure at which saturated steam has a temperature of 550° Fah. is 1,050lbs. per square inch. It was found, however, that to ensure transfer of heat, desirable to employ a temperature of 600° Fah., corresponding to a pressure of 1,575lbs. per square inch. An apparatus, consisting of a receptacle carrying a steam coil for heating a cast-iron crucible connected to a high-pressure boiler of special design, heated by gas, fulfilled the requirements. The details of the apparatus have worked reliably in practical operation, and it is possible to keep the metal in a melted condition at the desired temperature, ready for instant use, without more attention than a casual glance at the pressure gauge.

American Shipbuilding.—According to "Marine Engineering," over 1,500,000 tons of vessels are under contract in American shipyards, comprising 198 cargo boats, 91 tankers, 12 passenger and cargo steamships, 35 towboats, yachts, river boats, and other small steam craft, 60 or more sailing vessels, most of them with auxiliary power, 150 or more car floats, barges, &c.; and contracts are offered for 100 or more vessels if shipbuilders can find the steel and launching ways. During the past 15 years the average tonnage built in American shipyards has been about 250,000. To be added to the activity in merchant ships is the Government naval programme which calls for the building of over £120,000,000 worth of war vessels in the next five years.

BOILER EXPANSION EXPERIMENTS.

THE results of tests made on the New York Central Railroad system to determine relative movements of locomotive firebox sheets and tubes under working conditions are given by D. R. Macbain in the October issue of the "Railway Mechanical Engineer." The experiments showed that the expansion of the outer sheets was greater in every case than that of the inner sheets, which would seem to account for the breakage of the back head and throat sheets along the outer row of staybolts, also for the vertical cracks in the side sheets as well as the cracks extending from the arch tube holes. It was also found by means of a needle connected with the inner throat sheet and passing through the outer throat sheet that the inner tube sheet moved outward $\frac{3}{32}$in. when the fire was started, and before the circulation was fully established, and later, when steam

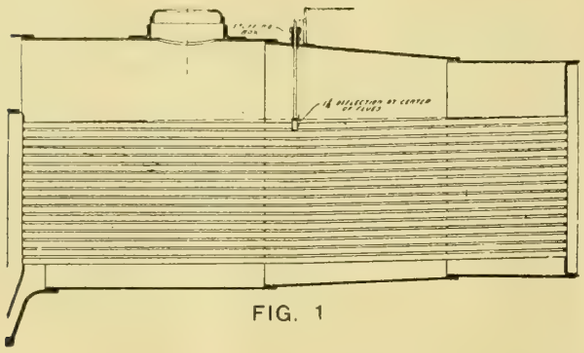


FIG. 1

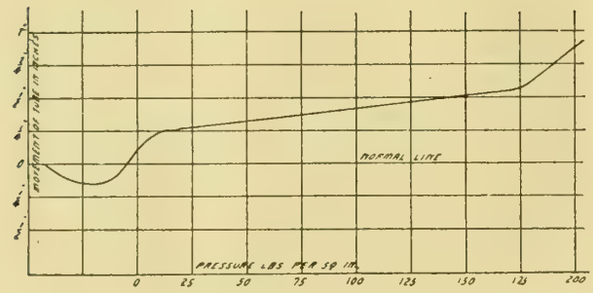


FIG. 2

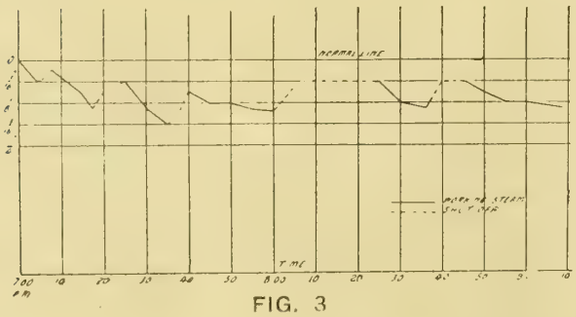


FIG. 3

pressure began to rise, backward about $\frac{1}{16}$in. The first movement throws some light on the cause of the side sheet cropping out along the fire line, as it does sometimes.

Another source of trouble was found with the breakage of staybolts in some of the wide firebox engines. It was believed previously that the cause of these bolts breaking was the same as that which was responsible for the leaky side sheet seams, and further that the elimination of excessive staybolt breakage would result in a cure for these leaky seams. With rigid bolts it was quite common to find anywhere from three to five or more bolts broken. An experiment was therefore tried on an Atlantic-type engine while it was undergoing repairs. A heavy template was fitted from the side of the boiler when the boiler was cold, and was firmly clamped at its centre to the boiler. The fit was very carefully made. The engine was then fired up and the effect of heating up the boiler to the point where 200lbs. of steam was obtained caused the wrapper sheet to bulge out so that there was $\frac{3}{32}$in. opening between the template and the wrapper sheet at both ends of the template. This apparently explains the cause of the breakage of the staybolts.

In order to determine whether this distortion of the boiler was caused by the pressure or the heat, the template was carefully refitted and a pressure of 225lbs. of cold water put on the boiler. The template retained its shape, which proved conclusively that the distortion was due to the temperature and not to the pressure. The application of three rows of flexible staybolts stopped the trouble and cured the leaky seams.

Experiments were also made to determine why the back and front tube sheets become deflected or distorted. It was believed that while the boiler was working and had a hot fire, the expansion in the boiler proper, that is, between the tube sheets, was greater than in the tubes. An experimental set of tubes was installed in a large Pacific-type locomotive, each tube being given a drop of $\frac{15}{16}$in. at the centre, but fastened at each end. A rod was fastened to one of the top tubes at the centre and extended up through a stuffing-box in the boiler shell, as shown in Fig. 1, the outer end being attached to a recording device which would register the movements of the tube. Fig. 2 shows the result of a standing test from the time the fire was started until 200lbs. pressure in the boiler was obtained. Almost immediately after the fire was started the tube deflected still more until it had reached $\frac{1}{8}$in. It remained in this position for a short time and then it rose and was about $\frac{1}{8}$in. above its normal position when the steam pressure began to rise. It rose gradually until 175lbs. pressure, and then rose rather abruptly. This rapid rise may have been due to the needle sticking a little in the stuffing-box. Fig. 3 is the record of another test, namely, on a road trip from West Albany to Rotterdam Junction. The solid lines are readings taken when the throttle was open, and the dotted lines with the throttle closed and the engine drifting. It is seen that immediately upon starting the tubes began to deflect, and rose when the engine was not working steam.

An investigation was also made to determine the direction and extent of expansion in a tube sheet resulting from prossering a set of new tubes. A circle of as large diameter as possible was described on the tube sheet, and after the tubes had been set it was found that this circle had increased or had widened out $\frac{1}{32}$in. at the side and bottom and $\frac{3}{32}$in. at the top. It has been the experience there that the 3in. radius for the tube sheet flange will give better results than the 2in.

Data on the relative movements of the back tube sheet to the throat sheet are given for the time from the moment the boiler is heated up and raised to 200lbs. pressure and released back to zero pressure. It was found that it is necessary to allow some freedom to the sheets longitudinally in order to avoid excessive strains being set up.

ASSISTANT ENGINEERS FOR THE MINISTRY OF MUNITIONS.

THE following letter has been issued by the Institution of Mechanical Engineers, Westminster, London, S.W.: Sir,—I have been requested by a Government Department to receive applications from a number of assistant engineers who would be willing to undertake work as salaried and whole-time officers. It is desirable that candidates for these posts should not only be well qualified, but experienced in the values of machinery and questions of depreciation of machinery. I know that many members of the Engineering Institutions, who are above military age or otherwise incapable of giving military service, are anxious to serve their country in a capacity in which their professional experience may be of value. The salaries for the positions in question range from about £250 to £400 per year. Applications should state age of the candidate, and, if he is of military age, why he is not in military service, and should give details of the candidate's qualifications, past training, and experience, and should be sent to the above address marked "Private." Suitable candidates will be interviewed by Captain H. Riall Sankey, C.B., R.E., and Mr. Charles L. Morgan, M.Inst.C.E., and will receive a communication on the subject of an interview in due course. I am, Sir, Your obedient servant, (signed) W. C. Unwin, president.

THE INTERNAL-COMBUSTION ENGINE.*

BY DUGALD CLERK, D.SC., F.R.S., M.INST.C.E.

(*Concluded from page 438.*)

THE engineering and commercial development of the 4-stroke engine proceeded simultaneously in England and Germany. The Messrs. Crossley, of Manchester, constructed many thousands of these engines, and as the result of study and experience they made numerous improvements of an important kind. The German works, the Gasmotoren Fabrik, of Cologne, under Dr. Otto, continued the work in Germany, and this company also constructed large numbers of engines; and Dr. Otto, Herr Daimler, his works manager, and others produced important modifications and improvements. All the numerous engine works established on the Continent and in America were enabled to work successfully from the experience produced in the first instance by these two firms. The early development of the engines, however, was seriously hampered by an erroneous theory of the action of the explosion under compression held by Dr. Otto and supported in Germany by a physicist even so learned as Dr. Slaby. This erroneous theory also received support from several English scientific men of eminence. According to Dr. Otto, all gas engines previous to his 4-stroke motor of 1876 obtained their power from the explosion of the homogeneous charge of gas and air. By this explosion excessive heat was supposed to be evolved, and the pressures produced rapidly fell away and the excessive heat was rapidly absorbed by the enclosing cold walls. This, Dr. Otto said, caused great loss and gives very wasteful engines. The two methods were open to obtain better economy: (1) by using a very rapid expansion so that the heat had but little time to be dissipated; (2) by using slow combustion, that is, by causing the inflammable mixture to evolve its heat slowly, so that the production of excessive temperatures and pressures was avoided.

The Otto and Langen engine, with its shooting piston, obtained its economy by long very rapid expansion; the Otto 4-stroke compression engine was supposed to obtain its economy by a gradual evolution of heat throughout the stroke, produced, as Dr. Otto thought, by the stratifying of a charge of gas and air in the cylinder. This false theory of the action of compression, if persisted in, would have blocked all improvement in power and economy upon the very moderate results obtained in 1876. The greater part of the credit of working out the true theory of operation of compression gas engines falls to Great Britain. A paper read by Clerk before the Institution of Civil Engineers in London early in 1882 discussed the theory of compression, and proved definitely and numerically the relative improvement in thermal efficiency to be expected by using compression previous to ignition. That paper, in fact, established the air standard of efficiency for internal-combustion motors. This was taken up later by Dr. Amie Witz, of Lille, and the whole subject was dealt with fully, so far as the knowedge at that time allowed, in a book published by Clerk in London in 1886. In that year also a paper was published at the Institution of Civil Engineers, also by Clerk, giving the results of investigations upon the different maximum pressures produced by mixtures of coal gas and air ignited at atmospheric pressure within a large closed vessel. In that paper the whole subject was dealt with quantitatively, and it was proved that the conditions of economy were, so far as explosion is concerned, due to the use of moderate temperatures produced by homogeneous explosive mixtures; stratification was proved to have nothing whatever to do with economy. Other investigators took up the work of Britain, and explosive experiments with various mixtures and pressures of gas and air were made both in American and German colleges which corroborated Clerk's results. The modern improvement of thermal efficiency flows from a knowledge of the true theory of compression, and by the aid of abstract knowledge the indicated thermal efficiency in commercial internal-combustion motors has risen from 16 per cent.—Otto's results in 1876—to 35 to 40 per cent.—results of high-compression engines used to-day. A very important portion of the work of investigation of the conditions of gaseous explosions is due to the Gaseous Explosion Committee of the British Association. That committee was formed at the Leicester meeting in 1907, and a great deal of important experimental work has been accomplished by its members in the nine years which have elapsed.

Notes on experimental investigation into explosion temperatures; rates of temperature rise and fall; dissociation of steam and carbonic acid; radiation during chemical combination and after; variation of specific heat of air, nitrogen, carbonic acid and steam with increase of temperature; causes of varying rates of inflammation; comparing closed vessel explosions with engine cylinder explosions, temperatures of cylinder walls and pistons; composition of exhaust gases, suction and exhaust temperatures; variation of heat loss during expansion at differing gas densities; internal energy of gases at high and low temperatures, and many other matters have been submitted and discussed by Callender, Clerk, Coker, Dalby, Dixon, Petavel, Harker, Hopkinson, and Watson.

Independent chemical work, too, has been accomplished by Bone, Dixon, and Smithells, while Burstall has made additional investigations on temperatures. The properties of the working fluid of the internal-combustion engine at high and low temperatures have thus become known to the engineer and inventor to assist him in making further departures intended to increase the power of those motors to compete more and more with the very large steam turbines and reciprocating steam engines of to-day.

Five reports have been published by the British Association summarising these separate investigations.

Germany has also carried out some investigations, principally at the Reichsanstalt, in Berlin. On the whole, however, the German scientific work on this subject is much inferior in importance to the British. Most valuable French work has been also done from Regnault to Mallard and Le Chatelier, Berthelot, and Witz.

Some American work has also been performed, but undoubtedly the English work on the nature of gaseous explosions dealing with questions of varying specific heat, rate of heat loss to walls, effect of polished inner surfaces, radiation effect, and the discussions on dissociation have proved of vital importance to the science of this subject. Curiously enough, the German scientific men are far behind in the theory of these motors, although their practical instructors have done excellent work, even with most erroneous ideas of the nature of the forces with which they were dealing.

The stationary internal-combustion engine industry grew very rapidly in England, and as will be seen from the figures already given, the German industry in 1907 was smaller than the English industry, and just before the war it is believed that the proportion of industrial engine work in England and Germany was practically the same as in 1907. An impression has grown in this country that Germany was more advanced in the application of internal-combustion power than we are here. This is due to the fact that the Germans have devoted much more attention to the large cylinder gas engine and oil engine than the British. English engineers have never been satisfied with the existing line of development of these large cylinder engines. From the scientific point of view they consider that the building of large engines practically without modifications of either thermodynamic or operative cycle was a costly mistake leading to development in a wrong direction. Accordingly in England more attention has been given to multi-cylinder engines than in Germany, the idea being to keep the dimensions of the cylinders as small as possible. By so doing, engines were produced of a greater power for a given weight of metal utilised. British engineers and scientific men are still convinced that other methods must be found of increasing power in internal-combustion engines than mere increase of dimensions of cylinders and massive construction of engine parts as practised in Germany. Undoubtedly a solution will be found which combines high powers with small weights. So far as stationary engines are concerned, cylinder for cylinder, the internal-combustion engine is at a disadvantage in weight for power compared to the steam engines without their boilers. A very large industry has been created in small cylinder engines, but the power unit attained as yet is not sufficiently great to compete with the larger steam engines, especially in

* Paper read before the Royal Society of Arts, November 29th, 1916. First delivered at Newcastle-on-Tyne, September 4th, 1916, at the meeting of the British Association.

the form of steam turbines. Notwithstanding the fact that English makers mainly confine themselves to smaller cylinder engines, it is a mistake to assume, as is too often done, that the Germans are in advance of us in this line of work, either in practice, industry, or science. While in Germany engineers paid great attention to larger cylinder engines, England was busy developing the smaller types adapted to use heavier oils, such as kerosene and paraffin. The first engine to attain success as a kerosene or paraffin engine was produced by Messrs. Priestman, of Hull, in 1885. Mr. Stuart Akroyd, in his patents of 1886 and 1888, described an engine which, in the hands of Messrs. Hornsby, has taken a most important position. In that engine air alone is taken into the cylinder of an internal-combustion engine through an inlet valve, and the combustion chamber is kept separate from the inflowing air by the device of using a chamber of bottle-neck construction, the bottle-neck opening into the cylinder. This bottle-neck combustion chamber is only partially water-jacketed, and one part of its surface can in the first instance be raised to a low red heat by means of a pressure lamp. The oil to be used is pumped into this combustion space during the suction stroke of the engine, but little or no mixture occurs until compression begins. The compression of the air by the piston on the return stroke forces the air charge to mix with the vaporised oil existing in the combustion space mixed with products of the previous ignition. The temperature of the hot wall is so adjusted that when compression is complete or nearly complete the mixture ignites and a moderate explosion pressure is produced. This type of engine is very successful, and is made in large numbers throughout the world. Other methods of operating internal-combustion engines have been experimented upon in this country by many inventors and manufacturers.

One set of experiments made by me possesses special interest. The experiments were made at Messrs. Tangyes' works in Birmingham at the end of 1887 and the beginning of 1888. In this engine the cylinder was charged with air on the 2-stroke method which I have already described. The air was compressed into a space at the end of the cylinder, and coal gas was compressed by a separate pump. When the motor piston completed the compression of air, the gas pump forced a jet of compressed gas into the compressed air, and an igniting device was so arranged that this jet ignited as it entered the compressed air. No gas was added to the air until compression was complete. The diagrams produced by this engine closely resemble those of the steam engine—a rise at the beginning of the stroke, constant pressure for a certain forward part of the stroke, then cut off and expansion. The engine, in fact, was as I called it at the time, a flame-injection engine in which explosion was avoided altogether. This engine ran for six months, and many tests were made. The explosion engine was held to have certain advantages which prevented this particular type from being put upon the market. Its interest arises from the fact that it was, I believe, the first engine operated by the injection of a flame jet into compressed air within a cylinder. Five years later Dr. Diesel, the distinguished German inventor, began work on an engine in which he compressed air through a range of about 12. Compressing air to one-twelfth of its former volume sufficiently rapidly raises the temperature of the air to about 600° C. Dr. Diesel then injected fine oil spray into this highly compressed hot air. The spray at once ignited, and a diagram very similar to the early Clerk diagram was produced, but at a much higher pressure with greater expansion, and therefore much greater economy.

Dr. Diesel was an able engineer of great pertinacity, and he succeeded in working through the great difficulties of this type of engine. It has, as we all know, become a most important feature of internal-combustion work. The Diesel type engines, with their high compression and automatic ignition, used for the first time very heavy oils in a most effective way. The Diesel engine undoubtedly fulfils important purposes in both stationary and marine work where oil can be had. Although it has taken an important place, and will continue to occupy an honourable position, its advocates have rather exaggerated its possibilities. The amount of oil in existence in the world is too small to allow of the future proposed by Diesel enthusiasts. For stationary purposes undoubtedly gaseous fuel prepared from coal or carbonaceous matter will maintain the leading position.

An interesting paper was read by Dr. Diesel at the Institution of Mechanical Engineers in the beginning of 1912, and in the discussion which followed, Diesel most honourably admitted the advantages he himself had derived in producing his engine from the study of earlier English work. Dr. Diesel's fate was a sad one. He worked with the utmost faithfulness and pertinacity from the initiation of his experiments in 1887 until his untimely death in 1913. He was lost, as you will remember, from the steamer "Dresden" on a passage between Antwerp and Harwich on September 29th, 1913. Notwithstanding his strenuous and useful work he died in great monetary difficulties. The period of existence of his patent in Germany and England was insufficient to enable him to reap any reward for his persevering technical efforts. This has proved the fate of many inventors, and the more important the invention the more likely is it that the term of the patent expires before commercial success is attained. Great departures are made with difficulty, while small changes are easily and rapidly applied. In the early stages of the Diesel engine the inventor was under the impression that he could produce a motor which followed the Carnot cycle in its entirety. Such an engine requires compression to the full temperature necessary for the addition of heat, expansion for a certain distance at constant temperature, and then further expansion to the lowest temperature, the heat discharged being obtained by compression at the lowest temperature. Such a cycle of operations gives the maximum possible efficiency between certain heat limits. Diesel misapprehended the position, and he failed at first to see that the mean pressure obtained in such a cycle was very low compared to the maximum pressure necessary. Thus, with a maximum pressure of 500lbs. per square inch the mean pressure was only 6lbs. per square inch. Such an engine would be, under the assumption, a perfect thermo-dynamic machine; but unfortunately it would give no power—friction would be too great. Accordingly the claim made by the supporters of Diesel in its early stages to a superior thermo-dynamic cycle from that of ordinary explosion compression gas engines falls to the ground. As a matter of fact the Diesel cycle has a smaller efficiency for a given compression than the explosion cycle.

Had coal gas been the only fuel possible for internal-combustion engines it could not have attained its position of to-day. In providing other gases for this purpose England also led the way. Mr. J. E. Dowson, in 1881, constructed a gas producer, using anthracite, which operated by passing a mixture of steam and air over the incandescent anthracite. The gases leaving this apparatus contained hydrogen, carbonic oxide, some carbonic acid, nitrogen, and a little oxygen, and when cooled evolved on combustion about 160 B.Th.U. per cubic foot.

The pressure gas producer which he first exhibited operated a Crossley gas engine in the year 1881 at the York meeting of the British Association. The invention of the Dowson pressure producer extended the sphere of these engines in a very material way, and led to the construction of what are called suction producers, operated without steam boilers or pressure blowers. Such producers have been applied very extensively in Britain and all over the world in units of from about 20 h.p. to 500 h.p. The suction modification was operated at first in France by the well-known engineer, Benier, in 1894, and the French development was continued in England and in Germany about eight years later.

England, too, led in the use of bituminous fuel producers; the late Dr. Ludwig Mond, of Brunner, Mond, & Co., devoted much time and effort to the production of large plants capable of gasifying bituminous fuels. In the larger plants Dr. Mond included devices for the chemical recovery of ammonia and the production of sulphate of ammonia. This work of Mond's has been most important, and many large installations of gas engines are now in operation up to about 3,000 h.p. using gas from Mond plant.

An English inventor, the late Mr. B. H. Thwaite, in 1895 made an important experiment in the application of the waste blastfurnace gas to the purpose of power production. His first plants were installed at the Glasgow Ironworks and at Barrow-in-Furness, and the idea was soon taken

up at the great Belgian works of Messrs. Cockerill. There the large cylinder gas engine was first developed. About 1900 an engine of 51in. cylinder diameter was exhibited as applied to blowing for blastfurnaces. This engine was the result of the work of M. Delamare Debouteville. This was the beginning of the large cylinder movement on the Continent. It was taken up in Germany by the Deutz Works, Cologne, and by the Oechelhauser Company. America followed, and in England, too, several makers devoted considerable attention to the large cylinder engines. The large cylinder movement has, however, undoubtedly prospered more on the Continent and in America than in this country. The extent of the trade, however, is not very great compared to the trade in small cylinder engines; and it is to be hoped that the efforts of British and other engineers will be successful in producing more powerful engines of less weight and bulk. The present large cylinder engine solution is by no means satisfactory, either to the engineer or to the scientific man.

The leading names in German invention and design are thus: Otto Daimler, Diesel, Oechelhauser, and Koerting.

British work in this line was accomplished by Crossley, Clerk, Robson, Atkinson, Humphrey, Priestman, Akroyd Stuart, Hornsby, Dowson, Mond, and Thwaite. The 4-stroke Otto engine, it will be seen, was adopted in England by Messrs. Crossley, and the 2-stroke engines of Clerk and Robson were adopted in Germany by Koerting and Oechelhauser.

Of the German inventors, Otto is by far the most important. Daimler's merit consisted in his appreciation of the fact that a 4-stroke engine of small dimensions could be safely run at a high speed of rotation; and his little petrol motors, from their relatively light weight and high power, were rapidly adapted by Germans, French, and Belgians to the purpose of motor-car propulsion. England, unfortunately, was hampered by an absurd law which required mechanically-propelled vehicles to be preceded on the road by a man carrying a red flag. This Red Flag Act was not repealed until 1896, so that after that date Britain rapidly gained headway in the construction of the very small cylinder petrol engine, and by its designers and scientific investigators shared fully in the modern development of the motor-car and the aeroplane. The aeroplane became practicable by the genius of the brothers Wilbur and Orville Wright in the United States in the year 1906. They were the first successfully to apply a petrol engine to a mechanical glider. America and France led the way with the aeroplane and the modifications of engine required for aeroplanes until 1909, when the Government Advisory Committee on Aeronautics was started, and the same year saw the beginning of the Royal Aircraft Factory. Another body, the National Physical Laboratory, in conjunction with these two institutions, made numerous experiments on the different factors required in flight. The co-operation of the three bodies in conjunction with the manufacturers of Britain resulted in the highly successful British aeroplane of to-day.

The industry devoted to stationary gas engines, oil engines, and petrol motors in Britain is now very large. An indication of the relative development in England and Germany is given by the comparison, by a well-known Belgian consulting engineer, Mr. R. E. Mathot, of the production of the Gasmotoren Fabrik Deutz and its licensees in Germany with the production of Messrs. Crossley Bros., Ltd., of Manchester, up to the year 1909. The German firm up to the end of that year had completed altogether 410,098 h.p. of stationary gas engines. The English firm had built 1,020,230 h.p., and this formed but a small part of the output of Britain. From this it must be evident to you that, acting in our own independent manner, Britain has accomplished a large share of the work of the development of the modern internal-combustion engine, both in design, construction, commercial manufacture and development of scientific knowledge. In some fields more work has been done in Germany, in others more in Britain.

So far I have discussed only the development during the modern period, that is, since 1876, but an earlier examination shows that as usual English inventors were very much alive to the necessity of improving the means of obtaining motive power. England and France in the early stage were at work long before Germany. This even the German textbooks acknowledge. In an important German work, written by a well-known German engineer, Herr Hugo Güldner, and published in 1903, I find the list of early inventors as follows:

1791. John Barber, English Patent No 1833.
1794. Robert Street, English Patent No. 1983.
1801. Lebon, French Patent No. 1799.
1823. Samuel Brown, English Patent No. 4874.
1833. Wellman Wright, English Patent No. 6525.
1838. William Barnett, English Patent No. 7615.
1841. James Johnston, English Patent No. 8841.
1842. Drake, English Patent No. 562.
1852. Christian Reithmann, experimental 4-stroke engine built in Munich.
1854. Barsanti and Matteucci, English Patent No. 1655.
1858. Degrand, French Patent No. 21301.

It will be observed that German industry appears under the name of Christian Reithmann for the first time in 1852. There are other early English inventors who do not appear in the patents list. Prof. Farish, Professor of Physics in Cambridge University, described an engine of the Lenoir type and showed a model working upon his lecture table as early as 1817. The Rev. W. Cecil, of Cambridge, produced an interesting atmospheric gas engine in 1820, and read a paper fully describing it before the Cambridge Philosophical Society in that year.

From this examination it will be seen that the internal-combustion engine, like all great inventions, is the result of a long-continued struggle, and much thought and ingenuity, the outcome of the work of men of many nations. It is indeed rare to find an invention which can be considered as entirely novel. A search through the records of the past invariably shows tentative efforts to produce a given result. The early efforts always failed, partly from want of fundamental knowledge—in the case of the gas engine, ignorance of the properties of gaseous explosions—and partly from the lack of engineering means of carrying inventions into practicable effect. It is one thing to conceive an idea and quite another matter to carry it into effect in actual operative iron and steel. In the early days of engines constructive appliances were exceedingly imperfect; and, accordingly, we find James Watt rejoicing when he gets a cylinder bored sufficiently true to prevent the passage of a coin between the cylinder and the piston at any point of the stroke. Great work had to be done and progress in machine tools made before it was possible to bore cylinders with the accuracy required in modern gas and oil engines. Progress is now more rapid on the constructive side, because machine tools are capable of an accuracy measured in thousandths of an inch, and also because of advancing knowledge of the nature of the working fluid, flame, which acts in the interior of those cylinders. The advance, too, of thermo-dynamics and the better understanding of limits of efficiency prevent inventors from following false paths. Accordingly we may expect further rapid advance in these motors during the next decade.

In this great subject, as in others, we have a right to be encouraged by the story of past effort and the realisation of the present, to look forward to a future in which Britain will perform her full share in the work of development and production. Broadly, development has been great and general, and the field of the reciprocating steam engine has been effectively invaded for both stationary and locomotive purposes on land and water. The steam engine in its various forms, however, still supplies much the largest proportion of motive power. The United Kingdom had stationary engines for manufactures and agriculture in 1907 of about 10·8 million h.p.; the United States had in 1909 about 23¼ million h.p., similarly mostly steam engines. Of this, in Britain, internal-combustion engines gave about 6·4 per cent. and America about 4·2 per cent. The engines on the ships of the world have a power of about 24 million h.p., a very small proportion internal combustion. The younger engineer of to-day has a huge field of effort open to him, and he will need all the scientific and practical knowledge available to fit him for his task. His position is enviable compared to that of the pioneers, and his progress should be rapid and great. The older combustion engineers have justified their

faith and earned an honourable position among the workers of the world.

The fate of the British Empire in the future depends upon the scientific engineer; our present existence as a free nation depends upon our sailors and soldiers; but the more distant future is subject more to the efforts of engineers than to the labours of war or politics.

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1915.

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Coupling for shafts. Luard & Willans. 17310.
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Bench for supporting and measuring a bar or tube length, and for feeding same to a cutting-off machine. Charles Taylor (Birmingham), Ltd., and Taylor. 18063.
Carburetters for internal-combustion engines. Robinson. 18088.

1916.

Transportable power winches. Hochon, P. L., and Gjorgjevitch, N. 817.
Carburetters for internal combustion engines. Soc. Lorraine, and de Luneville. 1061.
Gas fired melting furnaces. Hall, I. 1072.
Coal-cutting machines. Mavor & Coulson, Ltd., and Moore, M. S. 1155.
Means for adjustably securing the glands in piston rod stuffing-boxes. Lewis, T. J. 1531.
Chucks. Williamson, G. 1837.
Compression release-valve for two-cycle internal combustion engines. Martin, J. 2143.
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Trunk pistons of internal combustion engines. Albion Motor-car Company, and Murray, T. B. 9201.
Screw-cutting taps. Hall, G. N. 9378.
Open hearth regenerative furnaces. Clyde Furnace Company, and Dixon, W. 10341.
Process of welding and composition therefor. Hope, J. A. 10548.
Traction engines of the self laying track type. Caterpillar Tractors, Ltd. 11028.
Apparatus for actuating signals on trains and for stopping trains independently of drivers. Biddle, W. H. 12014.
Furnaces for heating, hardening, tempering, annealing, carbonising, and other processes. Smallwood, A. 12200 and 12201.

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Method of electric welding. Wilson. 18114.

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Mountings for electric switches and connecting apparatus. Mitchell, H. E. 679.
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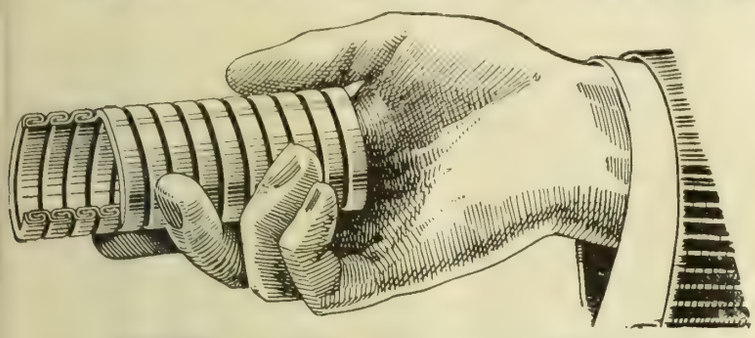

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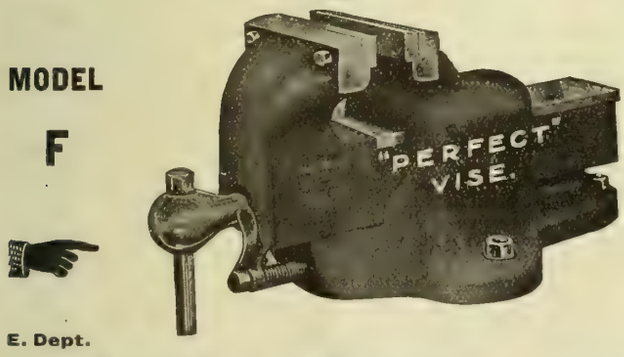

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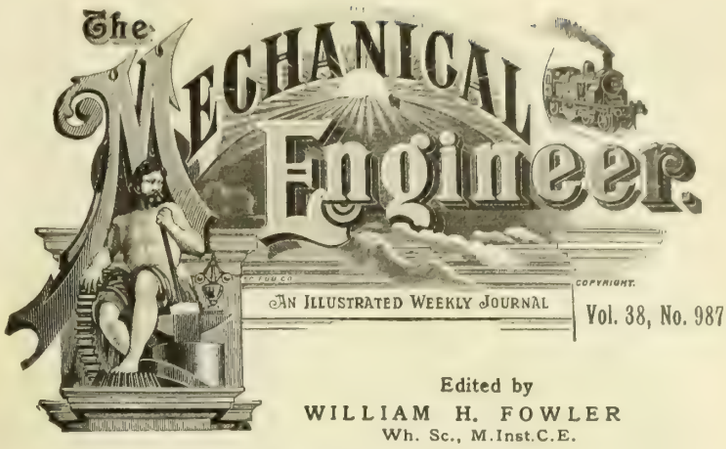

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German Electric Plant.

"THE Electrical Review" has rendered a good service to British engineers in presenting a record of the serious breakdowns of German electrical plant that have occurred in various parts of the world. The merits and cheapness of German plant have been so frequently extolled by interested persons, especially where large contracts are concerned, and the difference of price as compared with British quotations suggested a saving too great to be overlooked by municipal authorities or power corporations, that it is interesting and instructive to learn the experience of German plant in actual work. The facts revealed by our contemporary will be a consolation to many firms in this country who felt the pinch of an unfair competition resting partly on German methods of finance and partly on spurious appearances of economy attractive at the outset but ill-adapted to stand working conditions for any length of time on account of complex arrangements and improper material—on account, in short, of bad design. Nemesis has come at last and demonstrated once more the truth of the somewhat trite maxim in engineering "that cheap constructions are often nasty," and that "economy" at the beginning is often "dear" at the end. It is difficult, however, to impress this on purchasers, who often lack the technical knowledge and experience necessary for a correct judgment, and when things go wrong are reluctant to reveal the price they have paid for it. The most glaring of the failures in the list which is compiled by our contemporary is that of a 5,000 kw. A.E.G. turbo-alternator in the Riverside station of the Shanghai electricity department, and is the more striking inasmuch as the engineer-in-chief contrasts the experience of four A.E.G. turbines with that of six British machines which were under the supervision of the same staff, and which, although they have been from five to nine years in service, are in excellent condition, whereas three out of the

four German turbo alternators have in three years come to grief. As was perhaps only to be expected, the local agents of the A.E.G. have endeavoured to discredit the engineer's report, alleging that the turbines must have run at excessive speeds, that the faults were possibly due to defective switch gear, that supervision was inadequate, that the set had been allowed to get out of balance, and that the plant was not kept clean. In a reply the engineer, Mr. T. H. Aldridge, had no difficulty in completely refuting these allegations and in showing that the failures of the A.E.G. machines were due to errors in design, and this not so much from a theoretical as from a practical standpoint. The truth appears to be that the designers did not know how to attain their ends without introducing intricate and complex construction, which more than outweighed the slight gain in efficiency that resulted. In fact, they did not appear to know where to draw the line of "judicious compromise between the theoretically best and the practically expedient, with a bias perhaps towards durability and simplicity." It is in this trait that British engineers, as a rule, we are proud to say, excel. The result may not always secure the most efficient rating, and it may involve some increase in weight and cost, but it does secure longevity and reliability of the machine, which are of vastly more importance to the user, as he finds out to his cost when repairs and renewals have to be made. We are not pretending that every British-built machine is free from defects, but their reputation for durability stands on solid ground, and it is but just that in view of the unscrupulous methods which have been employed to secure orders for German plant that its defects, as revealed by the long list of failures collected by our contemporary, should be laid bare. At Sydney an A.E.G. turbo-alternator, purchased in 1913, broke down in the following year owing to defects in the turbine. At Melbourne a 5,000 kw. A.E.G. alternator gave way at the second diaphragm and fouled the blading of the rotor within three weeks of the set being put in service. Later other diaphragms were found to be in a precarious condition and had to be replaced with others of British make. Further on the blading was found to be unfit for use with superheated steam, and later other troubles developed which necessitated the rotor being replaced, the short experience fully justifying the statement of the engineer and manager of the company that "the behaviour of the set was considerably inferior to most machines of British or American manufacture." In an address by the President of the South African Institution of Engineers (Mr. Bernard Price) on the power supply of the Rand it was stated "it is not uncommon to meet with German plant which betrays every evidence of scientific knowledge when viewed from a purely theoretical point of view, but it is hopeless when viewed from a practical standpoint. The winding of a large alternator, for example, is complicated enormously merely to gain some slight benefit in rating but at the sacrifice of features which are infinitely more valuable to those who have to operate and maintain the machine." In support of this a number of instances were quoted in connection with plant supplied by German firms for South African power schemes. In one case six 4,000 k.v.a. alternators made by a German firm had to be entirely rewound, and seven 12,000 k.v.a. alternators had to be entirely rejointed. The design of these high-tension windings were, it is said, totally inadequate, lightning made short work of them; but in any event, it is added, their life could not have exceeded a few years. Numbers of sub-station transformers proved incapable of standing the stresses imposed at times of fault on consumers' circuits, and the method of clamping the coils had been entirely re-designed The high-tension switch gear for 40,000, 20,000, and 10,000 volts proved lamentably deficient, and it was added that it would be difficult to exaggerate the seriousness of the consequences which ensued, while the makers could suggest no better remedy than a duplication of the switches at the expense of the purchaser. Although the turbines were a good job in many respects, heavy maintenance charges were incurred on account of defective blading, and it became clear in the end that these originated mainly from faulty design. Subsidiary plant in connection with the turbines, such as steam pipes, valves, &c., were pronounced to be a most shoddy job. Flanges had to be re-expanded and riveted on and the whole of the lagging dismantled and replaced by material of better quality. The design of three electrically-driven compressors at another power station, it is stated, was a disgrace, and involved excessive cost in upkeep, the arrangement of inter-coolers and pipe work being such as to make it necessary to dismantle the compressor itself before they could be cleaned. At another plant, 12,000 k.v.a. three-phase German transformers had to be entirely rewound because the original winding was deficient in insulation and the surface of the copper conductors had been burned. The Tartar Hydro-electric Supply Company, Ltd., Bombay, not long ago installed four 8,000 kw. alternators, built by the Siemens Schuckert Company. As soon as these machines were put into commission serious trouble was experienced owing to the steel magnet rings of the rotors becoming loose on the spiders, which resulted in considerable delay in starting up as well as damage in the winding of one of the generators. In South Wales since the outbreak of war four 3,000 kw., 20,000 volt transformers have had to be rebuilt and rewound. In another case four A.E.G. transformers, rated at 3,000 k.v.a., 20,000 volts, with oil-cooling were found to be so badly designed that the purchasers decided to have them reconstructed and rewound before putting them into service. The failure of German plant on the North-east Coast is pretty generally known, though details, for one reason and another, have not been easily obtainable. It has transpired, however, that the A.E.G. obtained a large contract for 20,000-volt underground cable, but when this was laid they were unable to joint them properly. Three times the effort was made without success, and eventually the purchasers' engineers had to take the work in hand and adopt new methods. The same kind of trouble was met with in 12 to 15 miles of high-pressure cable supplied by the same firm for the Metropolitan District Railway, and here again in the end English jointers had to be employed for the purpose. Further, our contemporary states that cables supplied by a German company for connecting Charing Cross to Bow proved so defective when installed that it had to be entirely replaced. Other instances are quoted, but the above, we think, will suffice to expose the shoddiness of a great deal of German work, and it is to be trusted that purchasers of electrical machinery will make due note of it. The revelation is one of the good things which may be put down to the war, since it has enabled journals to speak their mind and denounce bad workmanship without the fear of an action for libel.

High Compressive Strength of Glass. — Compression tests on glass made a few years ago at Watertown Arsenal showed remarkably high strength. Samples 4in. by 2in. by 1in. tested on end showed strengths from 52,000lbs. to over 77,000lbs. per square inch for rough plate glass, and 45,000lbs. to 84,000lbs. per square inch for polished plate glass. A test on a much larger specimen was made recently at the U.S. Bureau of Standards. A cube nearly 10in. on a side was tested in compression. At relatively low loading the outer shell of the cube, ½in. thick or so, spalled off. The remainder of the cube was not seriously injured, however. The load was run up to the capacity of the machine, 2,400,000lbs., without breaking the specimen. The load at this time amounted to about 30,000lbs. per square inch.

CAST IRON : WITH SPECIAL REFERENCE TO ENGINE CYLINDERS.*

BY J. EDGAR HURST.

(*Concluded from page 461.*)

Machining.—It is interesting at this stage to turn our attention to the effect of machining on the resulting liner surface. It will be clearly evident that a similar surface disintegration, although much more severe in degree, is to be expected as a result of machining. Owing largely to the weak intercrystalline cohesion of cast iron under the influence of the cutting action of the tool, there will be a tendency for cracks to develop and travel along the crystal junctions. The extent to which these cracks will develop will depend largely on the strength of the iron and the force or severity of the machining. Professor Poliakoff has shown that the quality of finish, or shall we say surface, of a given material varies with the cutting speed: "the quality of the finish improves as the cutting speed decreases."† The deteriorating action of the rate of machining on the surface character of metal is more pronounced in the case of cast iron than steel.

It is extremely fortunate that the extreme accuracy necessary in liners and cylinders requires very careful machining, which must necessarily proceed at a comparatively slow rate. However, whatever the rate of machining, surface cracks and holes are found to a more or less extent. Such surfaces are very liable to rapid surface disintegration, at least for a time, and in addition to the delay in the production of the glazed surface the resulting excessive amount of disintegrated material is very liable to cause seizure. For this reason the comparatively recent method of internal grinding is a more preferable method of finishing liners than machining. Grinding has another aspect of great value in this connection. The glazing effect of the grinding wheel on the surface of the material is a phenomenon of the class already dealt with, *i.e.*, surface flow. It is also possible to produce appearances on the liner surface by means of the grinding wheel identical with those produced by a seizure. In addition the surface of liners which have been ground often possess in a degree the glazy appearance or very finely granular flowed structure. This is a distinct advantage, and in addition affords a means whereby the influence of this type of surface can be further investigated.

General Considerations on Growth.—After prolonged exposure to high temperatures certain cast irons are found to have undergone a permanent increase in volume. Percy, in his work on iron and steel, noted this fact, and incidentally suggested that this property could be rendered of practical utility in, for example, the rendering serviceable of cannon shot which had been cast too small in size. Of later years this question of permanent distortion and change in volume or growth was first brought seriously to the front by Alexander Outerbridge,‡ and was afterwards subjected to rigorous investigation by Messrs. H. F. Rugan and H. C. Carpenter.§

These investigators showed that the increase in volume takes place with greater rapidity and to a greater extent if the heating to which the cast iron is subjected be intermittent. The temperature at which growth appeared to commence was about 650° C., and it reached a maximum at about 750° C. At higher temperatures than this, say 900° C., very little further expansion was noted. The growth reached its maximum at any given temperature in the specimens used, after a period of three hours' heating, and continued heating over a period of 17 hours did not appear to make any appreciable difference. In addition to the gradual increase in volume a gradual increase in weight was also noted. They established the facts that (1) alloys not containing graphite do not grow, and (2) that alloys containing graphite are, under suitable conditions, capable of growing, and further, that the total growth was roughly proportional to the silicon content.

The total growth was far in excess of that caused by the dissociation of the carbide and the precipitation of temper carbon. This is recorded by Dr. Hadfield as being about 3 per cent. in those irons in which complete precipitation of the carbon in this form has taken place. The dissolved or occluded gases were also shown to have an influence on the final growth. It was proved that the growth was largely due to the influence of the furnace gases which penetrate into the cast iron by way of the graphite plates, and whilst in the hot state oxidise primarily the iron, and subsequently the silicon and phosphorus. Curiously, the graphite or free carbon appears to be the last constituent to be oxidised. A proof positive of the influences at work is to be found in the fact that on heating cast iron in a vacuum no expansion, but a slight shrinkage in volume, takes place; the same cast iron on heating in furnace gases expanded somewhere about 67 per cent. in volume.

Growth at Low Temperatures.—Cast-iron fittings, such as pipes and valves on superheated steam mains, after having been in actual service for some length of time, have been noted to deteriorate seriously. A marked falling off in tensile strength accompanied by slight permanent distortion and changes in volume takes place, and occasionally cracks have been developed. The average temperature to which such fittings are exposed is about 300° C. It is still very uncertain what is the exact mechanism of the changes taking place at such low temperatures.

Growth in Engine Cylinders.—In the internal-combustion engine, in particular, the material is constantly subjected to

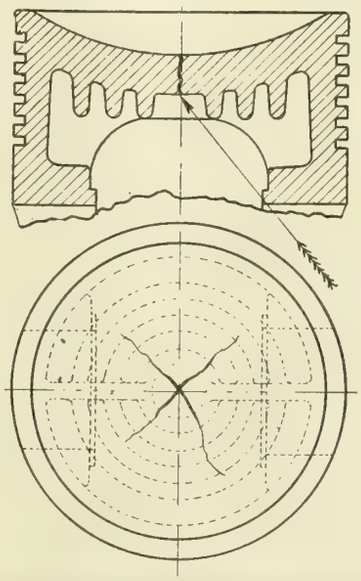


FIG. 1.—DIAGRAM OF DIESEL ENGINE PISTON HEAD SHOWING STAR CRACKS OPENING OUT FROM CENTRE.

increased and varying temperatures, and the study of the behaviour of grey cast iron under increased temperatures hence becomes of great importance. As a general rule, in internal-combustion engines the liner itself does not become unduly heated, owing largely to the efficiency of the cooling arrangements. At the same time it is undoubted that the temperature of at least the inner surface of such a liner, during actual working, is approximately in the region of from 200° to 300° C.

In the Diesel oil engine, the centre portion of the piston head is very often raised to quite a red heat, owing to direct contact of the piston head with the flame. This state of affairs is to be observed in gas engines; and in such engines working at full load, the piston head can be seen to have a dull glow in the dark. In the gas engine the temperature attained by the piston head is not nearly so high as is the case in the Diesel engine. After some time such overheated pistons become pitted and scaled in the heated area, and frequently crack in a manner as illustrated in the sketch, Fig. 1, the star cracks radiating from the centre of the heated area.

Heat Treatment of Grey Cast Iron.—To thoroughly understand this phenomenon it is necessary to become actually acquainted with the changes which take place in grey cast iron on heat treatment.

The effect of heat treating grey cast iron has been investigated by Dr. Hatfield.* In his experiments grey cast iron bars

* Abstract of paper read before the Manchester Association of Engineers, December 9th, 1916.

† First Report on Cutting Tools, Dempster Smith, Manchester Association of Engineers, 1915.

‡ Franklin Institute, January, 1904.

§ Journal Iron and Steel Institute, May, 1909.

* Journal Iron and Steel Institute, 1907.

were exposed for several hours to a temperature of 900° C. and slowly cooled over a period of 48 hours. A very serious falling off in tensile strength was noted, the tensile strength being reduced from 8 tons to 12 tons in the "as cast" condition, to 3 tons per square inch after heat treatment. (This is of great importance in view of the growing practice of annealing cast iron castings for softening purposes.) An examination of the micro-structures before and after heat treating revealed the fact that in the as cast specimens the graphite existed "in clear-cut worm-like forms," whereas in the heat-treated specimens "the graphite structure would appear to have swollen," which is "no doubt due to the free carbon produced by the dissociation of the carbide in the pearlite being drawn into position alongside the already existing graphite plates." These results have been confirmed by the author, and figures are given in Table I. The rapidity with which this precipitation of free

TABLE I.

Specimen mark.	Analyses.						
	CC.	Gr.	Total C.	Si.	Mn.	S.	P.
E1	0·50	3·35	3·85	1·87	·834	0·05	0·016
E2	0·50	3·51	4·01	1·79	·742	0·05	0·106
E3	0·47	3·17	3·64	1·87	·77	0·05	0·43
E4	0·44	3·08	3·52	1·89	·44	0·05	0·85

After Heat Treatment:

	E1.	E2.	E3.	E4.	Treatment.
Gr. %	3·72	3·62	3·33	3·29	750° C. for 2 hours, quenched in water
Gr. %	3·85	3·96	3·61	3·53	750° C. for 4 hours, " "
Gr. %	3·73	3·63	3·50	3·51	900° C. for 2 hours, " "

carbon is brought about even at so low a temperature of 650° C. to 700° C. is most striking. It is interesting to note that in the high phosphorus bars the rate of dissociation is somewhat retarded. This is confirmed on examination of micro-specimens from the above test bars, when it is found that the last of the pearlite remaining is that in juxtaposition to the phosphide eutectic. This is interesting to note, for it is generally found in grey foundry irons that some of the pearlite patches are in some manner connected with the phosphide eutectic, and are found in juxtaposition. In addition the graphite plates appear to have swollen, as pointed out by Dr. Hatfield.

Examination of the micro-structure of the heat treated specimens reveals interesting results. In one instance the specimens were quenched following upon the heat treatment, thus preserving in some measure the actual structure at this high temperature. The apparent swelling out of the graphite plates, leaving cavities, was particularly noticeable. A similar swelling out of the graphite plates was observed by Messrs. Rugan and Carpenter in the unoxidised centres of partially-grown cast-iron bars. Specimens cut from a high phosphorus cast-iron bar, heated to 890° C. for a protracted period, showed a distinctly granular appearance of the pearlite which is a characteristic feature of the heat-treated cast irons. The lamellar character of the pearlite was rapidly lost, and changed either into a "bead-like" or granular form, according to the temperature maintained during heat treatment and the cooling of the specimen.

The swelling out of the graphite plates was attributed by Carpenter and Rugan to the penetration of the furnace gases into the centre of the cast iron, and they also considered that the minute explosions of the dissolved hydrogen in the cast iron and the oxidising gases may assist in the expansion. The swelling out of the graphite takes place with extreme rapidity.

The changes taking place in the Diesel engine piston top, when subjected to the heating action of the flame during working, will now be clear. In the first place the expansion of the graphite plates, due to the entry of the oxidising gases, and simultaneously the dissociation of the pearlite carbide and the precipitation of temper carbon takes place. As a result of these internal changes which take place only in a localised area of the piston top, the iron is rendered, locally, considerably weaker, and large internal strains must undoubtedly be set up. As a matter of fact, however, the ultimate cracking of Diesel engine piston tops can, as a general rule, be traced to the phosphorus content of the cast iron, and providing this is kept sufficiently low this troublesome cracking is practically eliminated. In all probability this is due to a number of causes, the chief of which are set out below.

In the first place locally, at the centre of the star crack and in a superficial layer, the temperature attained by the cast iron is probably very high, at least in the region of 900° C. Specimens taken from this portion distinctly show liquation of the phosphide eutectic. This will undoubtedly increase the magnitude of the internal strains, and in addition at points in the region of this centre this same eutectic, at these temperatures, will be perilously near its liquation point. Both the elements, phosphorus and silicon, have a profound influence on the swelling out of the graphite plates. This influence is not yet thoroughly completed. Suffice it to say that to counteract this troublesome cracking the amounts of these elements present should be kept at a minimum. Furthermore, at high temperatures it is certain the high phosphorus cast iron is considerably weaker than low phosphorus cast iron, and under the influence of the high alternating gas pressures attained in the Diesel cylinder, such material will readily develop the star cracks.

Strictly speaking, however, this cracking is not actual "growth," for as a general rule very little oxidation beyond a superficial layer only can be detected. The change in volume which must necessarily take place, owing to the expansion of the graphite, is very slight in the piston as a whole, owing to the localised character of the heating, and is undoubtedly in a large measure responsible for the internal stresses. On cooling down such heat-treated cast iron, the swelling out of the graphite plates is in a large measure recovered, and particularly in the low phosphorus irons, apart from the deposition of the temper carbon, which appears to be drawn alongside the graphite plates, these plates assume nearly their original form. Briefly, it can be taken that the changes which have taken place in such heated and cracked Diesel engine piston tops are the very preliminary changes, previous to any oxidation, taking place in the well-known growth phenomena.

Chemical Constitution.—The question of the most suitable chemical composition for cylinders, liners, and pistons is a most important one, and involves an immense number of considerations, which increase the complexity of the subject enormously. Primarily, the properties required of cast iron for the manufacture of engine cylinders, liners, and pistons are: (1) Resistance to wear and maximum running properties. (2) Highest tensile strength and mechanical properties. (3) Resistance to growth and cracking when subjected to the high temperatures, such as are attained in Diesel engine cylinders.

It will already have been appreciated, and it is undoubtedly a very fortunate circumstance that the highest mechanical strength and good wearing properties in cast iron are practically synonymous terms. This statement is to be qualified, however, by the effects of surface flow and allied phenomena. The presence of certain elements in notable quantity, particularly the element manganese, undoubtedly have a large influence on the wearing and running properties combined. This influence is largely due to their influence in the production of glazy surfaces. High manganese cast iron more readily presents a glazy surface in an engine cylinder after use than low manganese irons. The element chromium is even more valuable in this respect.

The mechanical strength of cast iron rapidly falls with increasing temperatures. This is an important consideration in connection with surface disintegration, and it is very probable that the influence of manganese and chromium in increasing the resistance to wear, more particularly by surface disintegration, can be traced in some degree to their influence in the production of higher strength irons at high temperatures. Unfortunately, as yet, we have no figures to confirm this view. Table II. shows the influence of temperature on the mechanical properties of cast iron.

Mechanical Properties.—The mechanical strength properties of cast iron depend almost entirely, under normal conditions, on the state of the carbon and the grain size. In their turn these two factors are entirely controlled by the chemical constitution of the iron and the thermal treatment (by which is understood the casting temperature and the rate of cooling)

of the iron. It must always be borne in mind in mechanical strength considerations of a heterogeneous alloy, such as cast iron, that the arrangement and distribution of the constituents are quite equal in importance to the quantity.

TABLE II.

Temperature °C.	Bending Strength.	Inches, Bend.	Temperature °C.	Bending Strength.	Inches, Bend.
18	23·53 tons sq. inch	0·31	18	23·58 tons sq. inch	0·30
66	22·22 ,, ,,	0·30	85	21·90 ,, ,,	0·28
268	21·08 ,, ,,	0·28	155	21·27 ,, ,,	0·28
297	19·88 ,, ,,	0·30	370	21·02 ,, ,,	0·30
620	12·09 ,, ,,	0·55	580	16·03 ,, ,,	0·57
807	7·56 ,, ,,	0·94	810	6·16 ,, ,,	0·79

The most important factor in the chemical constitution is the silicon content. The average conception of the influence of silicon in cast iron does not appear to be quite correct. The researches of Dr. Hatfield,* Charpy, and Grenet, and others show that the influence of silicon is inseparable from that of rate of cooling. In Dr. Hatfield's experiments it was shown that the precipitation of free carbon does not occur with increasing silicon content in a gradual manner as generally conceived; but there would appear to be a silicon percentage, in this worker's case, between 1·4 per cent. and 1·7 per cent., at which the complete dissociation (for practical purposes) of the carbide and the precipitation of the free carbon is brought about. The amount or concentration of silicon necessary to bring about dissociation depends upon the rate of cooling.

This is substantiated by Hague and Turner,† who point out the ease with which the metastable conditions in the presence of silicon revert to the stable conditions and vice versâ. In their experiments on the iron-carbon-silicon alloys, at the white iron end of the series, slow cooling of the metal in the crucible, even with so low a silicon content as 0·03, left the metal quite grey, whilst on the other hand the slight chilling effect of a small platinum pin in connection with their extensometer instrument, embedded in the test bar castings and mould, was sufficient in certain bars to produce a local white fracture, whilst the rest of the casting was quite grey.

The importance of this is that it is approximately in the region of this point, *i.e.*, the point at which the silicon percentage coupled with the rate of cooling brings about the dissociation of the carbide content producing a "completely grey bar" that the closest-grained finely-divided graphite irons are obtained with consequently high mechanical properties. This is amply shown by the examination of specimens from the boundaries of the chilled and grey portions of chilled test bars. In such specimens the conditions of a constant silicon content with a gradually decreasing rate of cooling from the chilled edge inwards obtain. The portion at the boundary of the chilled and grey portion is that at which the rate of cooling is just sufficient to bring about the dissociation of the carbon content, which is inaugurated at numerous centres, and develops in some instances to a completely grey iron having a network arrangement of the phosphide together with very finely-divided, oft-times rosette formed, graphite.

The author would emphasize the advisability of employing a much lower silicon content than is usually the case in actual present-day practice. The analyses given in Table III. serve to illustrate this point. These analyses are taken from gas engine liners of very closely related cross-sectional area and illustrate admirably the apparent inutility of, in this case, the excess silicon content over approximately 1 per cent. There should be no difficulty experienced in the production of low silicon content cast irons. These are readily produced by the addition of varying proportions of either steel scrap or white irons to the cupola mixture. It should be pointed out that this is the only real advantage of the so-called semi-steel mixtures. In these low silicon irons the presence of those elements having a greater influence in increasing the stability of the carbide, such as sulphur, must be kept at a minimum. In the analyses in Table III. it will be seen that the presence of 1 per cent. of manganese in these low silicon irons still leaves the iron quite grey. Unlike manganese small percentages of chromium favour the retention of the carbide, and consequently, in such low silicon irons chromium must not be present in excessive amounts.

* Journal Iron and Steel Institute, No. II., 1916.
† Journal Iron and Steel Institute, No. II., 1910.

TABLE III.

Sample No.	Analyses.						Thickness of Casting.	Brinell No.
	CC. %.	Gr. %.	Si. %.	Mn. %.	S. %.	P. %.		
1	0·61	2·70	1·23	0·85	·072	0·93	⅞in.	228
2	0·68	2·68	0·93	1·04	·080	1·18	1in.	228
3	0·87	2·46	0·98	1·10	·090	0·89	1¼in.	228
4	0·64	2·38	2·04	0·84	·069	0·702	¾in.	196

The influence of casting temperature has already been indicated. Broadly speaking, it will be seen that the higher casting temperatures favour the retention of the carbide. This is in all probability due to the phenomenon of under-cooling. The metastable carbide phase is retained beyond its true dissociation temperature. The influence of casting temperature is more pronounced in the case of low silicon irons, as, for instance, the case recorded by Dr. Hatfield,* in which two bars of the following composition were cast, the casting temperatures of the two bars varied by 180° C. The higher casting temperature bar presented a mottled white fracture, whilst the other bar was quite grey.

Tot C	3·20 per cent.
Si	1·10 per cent.
Mn	8·41 per cent.
S	0·02 per cent.
P	0·20 per cent.

The necessity for controlling and standardising the casting temperature will be quite apparent.

In many instances the variation of the rate of cooling with a constant and somewhat higher silicon content is resorted to as a method of obtaining ideal engine cylinders. This method is peculiarly applicable to complex castings which would otherwise be difficult with a low silicon content to obtain sound. The variation in the rate of cooling is most generally effected by the use of chills on the cylinder barrel core, and a great number of locomotive cylinders in particular are cast in this way.

With the use of chills the same point can be arrived at with a higher silicon content as with the lower silicon content and normal cooling. In this connection it is interesting to note a peculiar phenomenon. The analyses in following table (Table IV.) are taken from various portions of a steam engine cylinder, as indicated in the table. The cylinder was chilled by means of ⅝in. chills attached to the barrel core. From the analysis it will be noticed that there is less combined carbon in the actual chilled face than in the portions which were not chilled. This is the result of the prolongation of the cooling period after solidification of the metal in contact with the chills, brought about by the highly-heated chills. This can largely be overcome by increasing the thickness of the chills.

TABLE IV.

Sample No.	Analyses.							Remarks.
	CC. %.	Gr. %.	Total C. %.	Si. %.	Mn. %.	S. %.	P. %.	
1	·303	3·00	3·30	1·70	0·82	0·08	0·66	Flange.
2	·18	2·98	3·16	1·72	0·79	0·077	0·66	Portion not chilled.
3	trace	3·33	3·33	1·68	0·92	0·079	0·64	Chilled portion.

These peculiar surfaces are close grained and of high tensile strength, consequent upon the rapid cooling during the pre-solidification period. They are, however, somewhat soft, and contain very finely-divided free carbon, possibly temper or annealing carbon, as a result of the dissociation of the pearlite carbide.

The question of the chemical constitution and its relation to growth and allied phenomena have been dealt with in a previous section. It will there be seen that one of the chief

* Proc. Royal Society, Vol. LXXXV., 1911.

preventative measures to be taken against those phenomena is the elimination, as far as possible, of phosphorus. From the point of view of wear and running properties this is not very satisfactory, and although very satisfactory running properties are obtained from cast irons in which phosphorus is absent, it is the author's opinion that the presence of phosphide eutectic improves these properties considerably. The use of chromium irons successfully overcomes this difficulty and, in fact, are much superior to any phosphorus iron. By reason of its profound influence on increasing the stability of the carbide, it is possible, by proportionately adjusting the silicon and chromium contents, to produce a grey iron in which the micro-constituent cementite (in this case the double carbide of chromium and iron) is disseminated throughout the whole structure. In addition, the other advantages of the presence of chromium have already been pointed out.

In conclusion, the author would emphasize the immense importance of the continued study of the application of cast iron to the design of engine cylinders and allied machinery parts. The advent of the internal-combustion engine and the consequent demand on all branches of the metallurgical industry for materials having the maximum physical and mechanical properties, is undoubtedly responsible for the great advance in the art and metallurgy of cast iron. At the same time, however, it should always be borne in mind that the field of complex high carbon alloys is still far from exhausted, and the author is convinced that, with the constant application of research in these realms, in conjunction with advance and improvements in the methods of manufacture, the labourer will reap his reward.

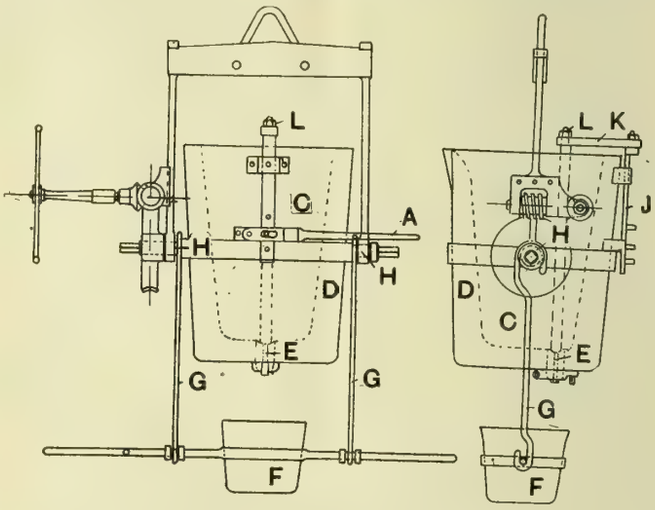
The author begs to tender his most sincere thanks to Messrs. Richard Hornsby & Sons, for their permission to use the greater part of the information contained in this paper; and also to Messrs. Mirrlees, Bickerton, & Day; to Mr. R. Onions, and the many other kind friends who have so readily placed information at his disposal.

THE VICKERS SURFACE-HARDENING PROCESS.

In a recent issue of the "Automobile Engineer," a description is given of the Vickers process of local surface hardening, which is comparatively little known. It consists of applying momentarily to the surface of the part to be treated an intensely hot flame from an oxy-acetylene blowpipe. The effect of this is to raise the surface of the object to a high temperature, it being then immediately quenched by the cold body of the metal beneath. The equipment is only that usually provided for the oxy-acetylene welding process, but the temperature of the oxy-acetylene flame is higher than that used for the latter process, the increase being obtained by adjusting the flame as for welding, and then slightly increasing the supply of oxygen. Arrangements should be made for keeping the work as cool as possible, so that the body of the work is maintained at a low temperature to ensure that the quenching is sufficiently rapid. For small parts it is customary to immerse the parts in a tank of cold water fitted with an adjustable overflow pipe. Bodies of large parts may be left to cool by themselves, but where necessary a supply of cold water may be allowed to flow over the work. In both cases the actual surface to be hardened is not submerged in water unless it is desired to give only a very shallow depth of hardened case. The process is most suitable for dealing with parts of which it is desired to surface-harden only a small portion. It is being largely used at the present time for gear-tooth hardening. In calculating the cost of the process for the purpose of comparison with furnace-treated work, it must be recognised that—whereas for the latter process it is customary for the machining of the work to be carried out to approximate dimensions only, so that any distortion due to the heat treatment may be corrected by straightening and grinding, or grinding alone, as the case may be—by the local surface-hardening process the work is machined to the actual finished dimensions, since there can be no distortion during the process. In a paper read before the Institution of Automobile Engineers, Mr. J. H. S. Dickenson, in November, 1915, pointed out that he had made several experiments to show the value of the process as applied to the local hardening of radii in parts subjected to high alternating stresses, and pointed out that the results of these tests went to prove that the limiting range of alternating stress in parts thus treated showed a considerable rise. Mr. Dickenson stated that, as a result, he was of the opinion that in the production of automobile crankshafts such local treatment of the radii had some obvious advantages.

METHOD AND APPARATUS FOR CASTING STEEL.

With a view to enable the easy elimination of the slag generally present on molten refined steel and other molten metals, and at the same time to deliver such steel or metal into the mould with the minimum of splashing and churning, Messrs. Robert and John Hyde, 20, Bannerdale Road, Sheffield, have designed and patented the method and apparatus illustrated herewith. There are two largely used methods, in the first of which the product from the melting, mixing, or refining furnace, mixed and contaminated with slag, is received in the well-known type of bottom-pouring ladle, fitted with stopper and lever for operating it. As the slag rises to the top, the steel, drawn from the bottom, is free from slag, but issues with considerable force due to the depth of the steel in the



Apparatus for Casting Steel.

ladle, and which increases, due to dropping to the bottom of the mould, causing considerable splashing, and also cutting or washing the mould to a considerable degree. To avoid this, in the alternative method, the steel or metal is poured over the lip or edge of the ladle, but it is a most difficult matter to hold the slag back from flowing over the lip at the same time, and contaminating the casting.

The method under notice consists in a combination of the two methods referred to into one unit. Referring to the illustrations, C is the body of a steel-casting ladle with usual fittings and lined with refractory lining D, having nozzle E through bottom, closed by stopper L. The mixed steel and slag are received in this ladle, and the slag rises to the top, so that when stopper L is raised by handle A, operated through slide J and link K, the issuing steel is free from slag, but issues with considerable force. This steel is received in a lip-pouring ladle F of convenient size and shape, with fittings as shown, which ladle is supported under ladle C by hangers or chains G depending from trunnion H. These hangers are detachable at either or both ends. The steel is then poured over the lip into the mould, and by virtue of the flexible nature of the hangers the position of the lip-pouring ladle F can be varied considerably in every direction at the convenience of the operator, enabling him to cast quickly and accurately, saving considerable time in adjusting position of ladle by crane.

Blastfurnaces in France.—The number of blastfurnaces in France in unoccupied territory is now 48 in blast, with eight ready to be blown in as soon as coke can be obtained. The furnaces use both French and foreign ore, and their present output is only from 110,000 to 120,000 tons per month. In July, 1914, just before the war, 45 plants had 116 blastfurnaces in operation, producing 420,000 tons of pig iron per month.

GRAPHITE CYLINDER LUBRICATION.*

BY E. W. JOHNSTON.

THE economy of utilising engine exhaust steam instead of steam direct from the boiler for all sorts of purposes is so obvious that one is led to wonder why the practice is not more universal. One reason which doubtless has mitigated against the method is the contamination of the steam by the oil used for cylinder lubrication. Now oil on a sea of troubled waters may bring comfort to the distressed marine engineer, but oil in steam beyond the cylinders or in the waters of condensation brings only trouble and grey hairs to the engineer, marine or otherwise. It is, in fact, not easy to find another substance which, apart from the one particular object for which it is employed, has so many disadvantages; and only the lack hitherto of any efficient substitute will account for its continued use as a steam cylinder lubricant. By a process of careful filtration combined with the employment of a coagulant, it is doubtless possible to obtain a condensate sufficiently free from oil to be fit for boiler feed purposes; but there is no system yet known capable of entirely eliminating oil from steam.

It is not unusual to find turbines advocated in order to provide such economical supply of pure steam; but turbines are not in all cases the most desirable form of prime mover, nor is it, perhaps, profitable to scrap otherwise excellent reciprocating engines in order to attain the object in view. The problem then is to find an alternative lubricant to oil, which, while fulfilling the same primary function, is free from its many disadvantages. Now graphite in certain forms is an excellent lubricant, and as such has already many valuable fields of usefulness. The discovery by Dr. Acheson of artificial graphite has, in particular, given to engineers a remarkably pure product, free from trace of grit in an unctuous form, which readily permits of its disintegration to a powder comparable in fineness with, say, fine pastry flour. I will only briefly refer in passing to the use of graphite in combination with oils or greases for steam cylinder lubrication, because, while the actual amount of oil necessary may thereby be appreciably reduced, the problem of oil contamination is not greatly affected.

Many attempts have been made to use powdered graphite alone, and one or two did attain a certain measure of success, but it was found after a time that difficulties arose. The graphite would accumulate, for instance, behind the piston rings, clogging their free movement, and resulting in scoring of the cylinders. This clogging also extended to the ports and pipeways, and even to the condensers, and generally, I believe, the use of graphite in powder form has fallen into disrepute. Late in 1906, Dr. Acheson, in the United States, discovered that by a process of what he terms "deflocculation," he was able to carry the subdivision of graphite much beyond that attainable by ordinary means. The new product thus obtained was introduced into this country at the end of 1911, and in one of its forms is known as "Aquadag," or "Deflocculated Acheson Graphite," in water.

It is not possible in the time at my disposal to describe in detail the evolution of this interesting discovery; suffice it to say that Dr. Acheson found that by mixing a weak solution of tannin with his disintegrated lubricating graphite, known as "1340," and agitating the mixture, the minute pieces of graphite were broken asunder. The extremely fine particles of graphite thus produced show no tendency to cohere. Let it be remembered that by the prior process of disintegration the graphite particles are already reduced in size to a diameter of less than $\frac{1}{338}$in., and are therefore small enough to pass through a sieve having 40,000 meshes per square inch; but to such an extent does this deflocculation or breaking down take place, that each of these very small graphite particles is subdivided into about 1,000 parts. This minute subdivision is almost beyond the power of human comprehension, but a comparison may be drawn with the particles of dust present in the air, which are invisible in ordinary light, but may be seen in a sunbeam. The particles of deflocculated graphite are so small that under similar conditions sunlight would fail to render them visible; are so small in fact that they will pass through the finest chemical filter paper almost as readily as pure water.

Dr. Charles Mabery, professor of chemistry at the Case School of Applied Science, Cleveland, Ohio, in a paper read before the American Society of Mechanical Engineers in January, 1910, gives the results of tests carried out with Aquadag in comparison with various oil lubricants on a Carpenter testing machine, which showed that both the coefficient of friction and rise in temperature for Aquadag were very considerably lower than for any of the other lubricants tested. We have here, therefore, a remarkable new lubricant, chemically inert in pure water, a medium convenient for application at least for internal lubrication, and of such extreme fineness as to be capable of readily entering the pores of metals, evening up their surfaces and forming a coating of high durability and exceptional lubricating properties.

Another remarkable feature of Aquadag is that numerous and long-continued trials show that the very small proportion of 0·35 per cent. (one-third of one per cent.) of graphite to water is adequate, and that a larger proportion is superfluous. Further, Aquadag cannot emulsify, oxidise, or burn up, and, unlike oil, possesses little or no viscosity. Hence regulation in feed, for instance, is not affected by temperature. Its cost compares favourably with that of oil, and as it is sent out in concentrated form (a one gallon charge weighing only a few ounces) is economical in freightage and storage. As a cutting medium instead of lard oil, &c., it has already established a reputation; and in the drawing of tungsten, &c., for metallic filament lamps, Aquadag is the only lubricant used for practically the whole world's production; in fact, it was found that the process of drawing tungsten, &c., wire was not a commercial proposition until Aquadag was used.

The subject of this paper, however, is "Graphite Cylinder Lubrication." My knowledge of other applications of graphite is probably less than many of you here possess, and certainly does not entitle me to give more than a passing reference to the same; but as the first to systematise the use of Aquadag for steam and other cylinder lubrication, I have ventured to hope that my experiences in that direction may prove of some little interest to you. It was in the early part of 1912, while searching for means of economically overcoming the difficulty of oil contamination in the feed water, and particularly in the exhaust steam, that I became aware of the existence of Aquadag. Although the vendors were then unable to recommend its use in this direction, I considered it worth trying and obtained a small supply. The results obtained with this, so far as effective lubrication is concerned, appeared sufficiently promising to encourage further tests, but I found difficulty in arranging for continuous and graduated feed. An ordinary water-filled sight glass was, of course, useless, and a steam-filled sight tube, which was tried, became obscured almost immediately.

Yet in view of what I knew of the failure of previous attempts to use graphite arising from "clogging," I soon realised that for the deduction of reliable data some means of accurate feed control must be found. Lacking knowledge of the existence of any such means, I therefore devised a lubricator having as its distinctive feature a sight tube filled with paraffin or other transparent oil instead of water, and having the feed nozzle at the top instead of the bottom, where now was placed the outlet connected to the steam pipe. This formation can best be described as an upright U, one arm of which (the sight tube) is filled with some non-aqueous liquid, through which the aqueously borne lubricant is fed drop by drop, rising and filling the other arm of the U formed by the delivery tube, passing thence to a suitably constructed outlet, whereby it is "atomised" into the current of steam, and so conveyed to the moving parts of the engine. Contrary to what might be expected, the oil does not pass upward through the nozzle, and difference in specific gravity prevents its escape up the delivery arm. Difficulty was at first found in obtaining a satisfactory drop feed, owing to pulsation at the nozzle, but this was eventually traced to "air cushion" above the oil in the sight tube and elsewhere, and this defect has now been entirely eliminated.

In order to prevent dilution of the lubricant by displacement water from the condenser, I designed the container in such form that a body of oil is always interposed between them; means are also provided to prevent the oil from escaping either by way of the condenser or into the sight tube. This sight tube is equally applicable to mechanical or other force feed lubricators as to the displacement type described.

* Abstract of paper read before the Birmingham Association of Mechanical Engineers, November 4th, 1916.

The latter, however, has many points of practical utility not possessed by the displacement type in general use for oil.

Lubricators embodying the above principles were made and fitted by me, and Aquadag was adopted as cylinder lubricant in February, 1912. The plant concerned includes three 50 kw. high-speed steam dynamos, two deep borehole pumping engines, boiler feed, circulating and other steam pumps, supplied with saturated steam from three 30ft. mechanically-fired Lancashire boilers working at 120lbs. pressure. It was early noticed that one dynamo engine, the high-pressure cylinder of which had a bore varying in circumference about ⅛in., ran more smoothly than it previously did on oil; also the usual three-weekly inspection of cylinders showed that the general impression of efficient lubrication was well founded. One of these high-speed engines, after accurate gauging of the valves and cylinders, was put on a six months' running test. At the end of this period the greatest wear at any point was found not to exceed one-thousandth of an inch, and it was particularly noticed that the walls of the high pressure cylinder and piston rings were in faultless condition, having mirror-like surfaces. A set of indicator cards were taken on full load after about two years' working on Aquadag and a comparison made with those filed by the engine makers of the official works test of this engine. The results showed a difference in overall efficiency of 0·6 per cent. only, which, considering the test was made under ordinary working conditions, may be regarded as satisfactory. A steam consumption test would have been made had working conditions allowed, but this was not practicable, the engines exhausting into a general heating, &c., system at 3lbs. back pressure.

As demonstrating the formation of a real graphitic coating on the rubbing surfaces when Aquadag is used, it is interesting to observe in certain cylinders composed of more open or porous grained iron, how the graphite has evened up the minute depressions.

Since uniformly satisfactory results were obtained also on the pumping engines and other auxiliaries, the stock of cylinder oil became obsolete, and has been sold and quite forgotten. The entire plant has, therefore, been working with Aquadag as the sole cylinder lubricant from February, 1912, up to the present moment. All available condensed steam is now returned to the boilers, so that approximately 10 per cent. only of make-up water is added daily. The interiors of the boilers are free from grease, practically clean down to metal save where patches of old scale still adhere, and entirely free from suspicion of "pitting." Formerly a considerable amount of scale of very tenacious character had to be dealt with, which resulted in loss of efficiency, extra labour, and wear and tear to the boiler. Now, on the other hand, a feed water of considerably higher temperature and exceptional purity is available, resulting in further considerable fuel economy. This latter is obtained at no extra cost of, or inefficiency in, lubrication, and without the considerable expense of installing and maintaining a water softening or oil filtering apparatus; which latter, owing to existing arrangements, pipe levels, &c., is often impracticable. Further, the employment of a chemical filtration process for oil elimination purposes must appreciably reduce the temperature of the treated condensate. It also leaves untouched the problem of oil deposition in condensers, radiators, &c., and forbids the employment of exhaust steam in contact with foods and other delicate products.

This system having now been in continuous operation for about five years, ample time has been allowed for the development of possible defects arising from (1) insufficient lubrication, (2) clogging, and (3) the presence of the graphite in the boilers and steam system generally.

(1) In regard to lubrication, the continued excellent state of all rubbing surfaces, including slide valves, which are without trace of scoring, dispels all doubt on that head. As illustration of the little wear obtaining, may be adduced the fact that it has not yet been found necessary to face up or replace a single working surface save two piston rings, one of these having broken by accident during withdrawal for inspection. These results may be said to no more than bear out general experience of the efficiency of graphite in reducing friction, when suitably applied; but past experience may also be adduced to show that, as an inert solid, graphite, however applied, must build up deposit on deposit, and so interfere with the free working of pistons, valves &c., and produce clogging of the ports and pipeways. If Aquadag so operates, its use for internal lubrication must, like that of previous attempts to employ graphite alone, be regarded as a failure. Hence the long probation imposed by the writer on his system.

(2) Under the general term "clogging," I will include any undesirable accumulation or deposit of graphite on the piston, cylinders, valves, in glands, ports, condensers, steam exhaust and water pipes, and boilers. Let me again draw your attention to the extreme fineness of the graphite contents of Aquadag. Here we have the law of gravity set at defiance by the permanent state of suspension in water of the comparatively heavy graphite particles. Let me also remind you that, while this state of suspension is stable in pure water, even between fairly extreme degrees of temperature, evaporation to dryness will restore the power of cohesion lost during deflocculation. Carry out this evaporation to dryness by a gradual process, and a solid mass of graphite will result. Suppose, however, an evaporative process takes place while the graphite particles are very widely diffused, as occurs after "atomisation" of Aquadag correctly injected into a curent of steam. What is likely to result? Probably cohesion now only occurs to a trifling extent between the particles themselves, but will more readily result from collision of the particles with the surfaces traversed by the steam current. If the correct amount of Aquadag has not been grossly exceeded, and has been evenly injected (as by a drop by drop feed), the current of steam is probably too strong to allow of more than a thin graphitic coating; and when this coating has been obtained, further adhesion is more or less confined to replacing those particles lost by friction.

Those graphite particles remaining in the steam, after passing through the engine, will again meet and become entrained in moisture from the water of condensation. In this state, though now flocculated and out of suspension in the steam, but still finely subdivided, the graphite appears to possess little immediate power of further coherence, and is probably carried by the nearest "condense" drain to the hotwell, and from there to the boilers. Further, the amount present at any one time beyond the engines is so small that it may easily pass undetected. For consider what is the actual amount of graphite involved; the proportion in Aquadag as used is one-third of 1 per cent., so that, allowing 277 cub. in. to the gallon, this gives, approximately, 0·92 of one cubic inch only of graphite for every gallon of lubricant passed through the engines. This is my own explanation for the fact that, after almost five years' daily use, there is found to be no deposit throughout the receivers, ports, valves, and cylinders in excess of the thin coating formed in the first few weeks of use; and little, if any, trace in the exhaust pipes, condensers, or other tracts beyond the engines.

(3) The effects of graphite in boilers, &c., can only be advantageous, and, in fact, the direct insertion of graphite is now advocated. Being chemically inert, it cannot form combinations likely to injure the metal surfaces of the plates or mountings, but is more likely to protect them. It would also appear to have a real effect in reducing scale formation.

It is to be understood that this paper is founded upon experience gained in the employment of Aquadag in connection with engines running on non-superheated steam, and the writer is not entitled to speak as to results which might be derived in conjunction with superheated steam, although he has reason to suppose that in one instance, at least, his system is giving satisfactory results where some degree of superheat obtains. There is, however, no question as to the ability of deflocculated graphite to afford efficient lubrication; but practical difficulties in the way of "atomising" it into the current of steam yet remain. Experiments made by the writer, however, lead to the conclusion that the problem is capable of solution.

For the internal lubrication of air compressors, Aquadag would appear to possess at least one outstanding advantage over oil, inasmuch as it is not liable to cause explosions which not infrequently are of a fatal character; and a start has been made in the adoption of this system to high compression, but it is yet too early to give the results.

In the use of Aquadag for the cylinder lubrication of internal-combustion engines, many interesting problems are involved, in the elucidation of which the writer hopes it may be his privilege to assist.

DIRECT-CURRENT MOTORS IN THE STEEL MILL.*

BY H. F. STRATTON.

IN this paper reference will frequently be made to two or more motors mechanically connected. The phrase "mechanically connected" will be defined as meaning first, that any change in speed of rotation of any one motor must be accompanied by the same proportionate change in speed of rotation of each of the other motors; and second, that a change in the direction of rotation of any motor must be accompanied by a change in direction of rotation of each of the other motors. This definition is made broad enough to include the infrequent

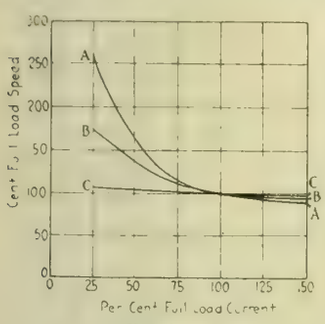


FIG. 1.
Relation between Speed and Current of various Types of Motors. AA - Series Motor. BB—Compound Motor. CC—Shunt Motor.

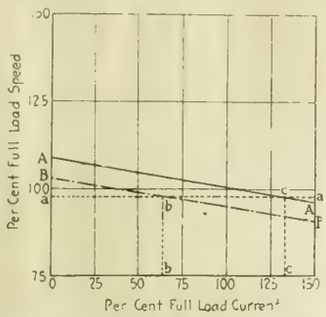


FIG. 2.
Speed Current Curves of two similar Shunt Motors.

cases where two or more motors of different horse-powers and speeds are operating together to drive one motion, and the more frequent cases where the motors may be identical in horse-power and speed but may rotate in opposite directions. The majority of cases claiming our attention will include two or more motors of the same horse-power and speed, all rotating in the same direction at the same time. The mechanical connection between motors may consist of gearing, pulleys and belts, sheaves and cables, or it may be through track and track wheels as on the bridge motion of a travelling crane.

Electric cars furnish an early example of two motors mechanically connected. One reason for their use in this work is the small clearance between the track and the bottom of the car; another reason is the economy in power consumption which is gained by the use of series-parallel control. The steel mills furnish frequent illustrations of two or more mechanically-connected motors, and it is logical to enquire why preference is given to several mechanically-connected motors instead of one large motor having a horse-power rating equivalent to the sum of the smaller motors. In some cases two or more motors were used simply because of their convenience. It may be that the frame of the smaller motors fitted more easily in the available space or that it appeared to be considerably easier to change armatures. Sometimes the horse-power requirements are quite large, and if one large motor instead of several small ones were used, it might introduce into the mill an entirely new size of motor, thereby complicating the spare part situation; or the horse-power rating might be beyond the range of mill-type motors, thereby forcing the use of a motor which did not seem to have the same sturdy qualities that characterise mill-type motors. Another reason, and a very good one, for the use of two or more mechanically-connected motors is the need of continuing to operate some machine, even if one of the motors burns out. In this case the remaining motor, or motors, are made of sufficient capacity to maintain operation, although perhaps at a reduced speed. A metal mixer is a good illustration of a machine coming under this classification, as it is obviously necessary to be able to tilt the mixer even if one motor is disabled. The hoist on a ladle crane is another common illustration of the same character.

It has come to my attention several times that two or more mechanically-connected motors have been selected for roller-table service on the theory that the small motors will accelerate and reverse more rapidly than one large motor, and that therefore a roller table so equipped has a larger capacity to move steel. Probably this belief was based on the fact that so far as mill-type motors are concerned, the moment of inertia generally increases a little more rapidly than the horse-power rating. For instance, the moment of inertia of the armature of a 25 h.p. motor is apt to be less than one-half the moment of inertia of the armature of a 50 h.p. motor. There is an error or omission in this reasoning to which I shall refer later. I have also heard of the use of two mechanically connected motors permanently in series, advocated for roller table service on the theory that acceleration or reversal was as rapid up to half speed as in the case of one or more motors receiving full-line voltage, but with the added advantage that the two motors in series did not have the same tendency to race if allowed to run for a length of time. It was felt that this made reversing quicker and easier for the motors. I have also known cases where steel mill engineers have felt that there should be a worth while saving in the cost of the controller for two motors mechanically connected and permanently in series.

The foregoing illustrations are those which have come to my attention from time to time favouring the use of two or more mechanically connected motors in the place of one large motor, and no doubt other reasons could be stated. This practice, however, has raised new difficulties, some of which can easily be explained by theoretical considerations; others, however, are brought to our attention forcibly only by the difficulties experienced in service, and sometimes it is puzzling to find the true explanation of the difficulties which have developed. The electrical problems, which are very largely the questions of circulating currents and the unequal division of the total motor current, are important and will be considered first.

The following is the general equation of a direct-current motor: The speed of rotation is equal to the voltage divided by the product of the number of effective armature conductors and the amount of magnetic flux which is cut by these conductors. The characteristic curves of series, shunt, and compound motors are merely graphic illustrations of this fundamental equation bringing in, in addition, the variation of motor current as a function of speed and the variation of torque as a function of current. It will be more in line with our purpose to show curves for series, shunt, and compound motors, illustrating the change in motor current with change in speed. It is, of course, well known that the speed changes least in the case of shunt motors, more in the case of compound motors, and most in the case of series motors.

In Fig. 1, curve *AA* represents the relation between speed and current in the case of a series motor, *BB* in the case of a compound motor, and *CC* in the case of a shunt motor. These are curves expressing current as a function of speed. It must be remembered that such a curve represents only approximately the performance of any given motor, and, as a matter of fact, the speed-current curves of different motors, although built commercially to be duplicates, will vary by several per cent. Take the case of any standard motor. Undoubtedly all such motors built from the same drawings and patterns will have the same general physical dimensions, the same number

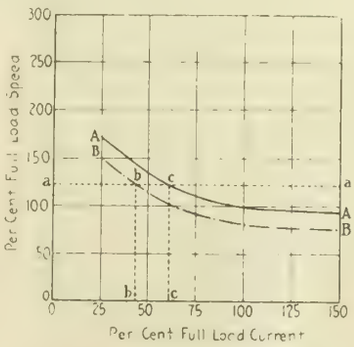


FIG. 3. Speed Current Curves of two similar Compound Motors.

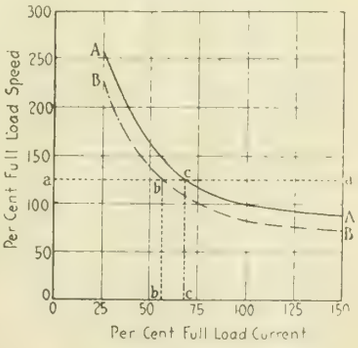


FIG. 4.—Speed Current Curves of two similar Series Motors.

of effective armature conductors, and the same number of turns in the field coils. It must be remembered, however, that the position of the speed-current curve is strongly affected by the total flux which is cut by the armature conductors. In each case the voltage may be the same, the armature and the field coils may be the same, but the total flux may vary considerably, because the reluctance of the iron

* Paper read before the American Association of Iron and Steel Electrical Engineers, November 4th, 1916.

circuit of the motor will depend on the character of iron employed and upon the lengths of the several air gaps.

In Fig. 2, the full line *AA* is the speed-current curve of one shunt motor, and the dash line *BB* is the speed-current curve of another shunt motor, which might be easily sold as a duplicate of the first-named motor. The only difference between these two curves is that at any given load, one of the motors has a speed 5 per cent. in excess of the other motor. If two such motors are connected to a machine so that they must rotate at the same speed, there will necessarily be a heavy unbalancing of the total current. For instance, assume the load is such that the two motors will run at the speed indicated by the line *aa*; it will be seen from the diagram that one motor will then take 65 per cent. full load current and the other motor 135 per cent. full load current. The two motors together are taking twice the full load current of one motor, but one motor is considerably under-loaded and the other motor so much overloaded that it will burn out if the load is maintained.

Fig. 3 indicates the conditions which might be expected in the case of compound motors, and Fig. 4 the conditions in the case of series motors. It will be noted that the unbalancing of mechanically-connected series motors will be less than the unbalancing of either shunt or compound motors. The unbalancing of compound and series motors is least at high speed and low current and greatest at low speeds and high current.

So far we have not considered the question of control, but have merely reached the conclusion that, due to imperfections in motor manufacture, two or more mechanically-connected motors are apt to divide the load unequally, and that this difficulty is least serious with series motors, more serious with compound motors, and most serious with shunt motors. Several other causes might lead to similar variations in the speed-current curves. Unequal heating of shunt field coils, failure to rewind armature or field coils with the original number of turns, poor condition of commutator or brushes, or greater drop in line voltage in leads to one motor than in leads to another motor, are examples of these causes. In short, there are many reasons why two or more mechanically-connected motors, nominally duplicates, will make an unequal division of the total motor current.

Two series motors are sometimes controlled by a single, standard, one-motor controller by connecting the two series field permanently in parallel and the two armatures permanently in parallel. Fig. 5 represents such a condition wherein FF_1 is the series field of one motor, SF_2 is the series field of the other motor, A_1 is the armature of one motor, A_2 is the armature of the other motor, F_1 and F_2 are one pair of reversing contactors, and R_1 and R_2 are the other pair of reversing contactors, S_1, S_2 and S_3 are the acceleration contactors which are used for short-circuiting the resistor. The entire motor current flows through the two series fields in parallel, which are of relatively low resistance; as the current will divide inversely as the resistance of the two fields, it is a delicate and difficult matter to balance these two circuits so that they shall divide the current equally, not only when the motors are cold, but also when they are hot. The general result is that more current flows through the series field of one motor than through the series field of the other motor. The motor having the smaller portion of current through its series field will have less total flux to be cut by the armature conductors; it will therefore develop less counter-electromotive force than the other motor, and will permit a considerably higher current to pass through its armature. The motors will, therefore, be unbalanced, not only because of imperfections in manufacture, as shown in Fig. 4, but, in addition and more seriously, because the total flux of one motor will be larger than the total flux of the other motor. The conclusion of this analysis is, therefore, that the operation of two mechanically-connected series motors by one controller may lead to serious unbalancing of the current.

The first departure from this scheme of control is one probably suggested by the practice followed on electric cars. Here it is usual to employ one starting resistor, but to have individual reversing switches for each motor. These connections are shown in Fig. 6, wherein the designations are the same as in Fig. 5, with the exception that F_3, F_4, R_3 and R_4 represent an additional set of reversing contactors. With individual reversers for each motor, it is possible to connect the series field of one motor directly to its armature and the series field of the other motor directly to its armature. This connection eliminates the unbalancing due to unequal division of current through the series field, as explained in connection with Fig. 5. It is a satisfactory connection for two mechanically-connected series motors when these motors are merely started from rest and accelerated to receive full line voltage. The only unbalancing of load is that due to variations in the speed-current characteristics of the two motors.

I have said that the connections in Fig. 6 are satisfactory for accelerating the motors from rest to full speed. They are not satisfactory for rapid reversing or "plugging," the difficulty being one of circulating currents at the moment of reversing. Fig. 7 indicates two mechanically-connected motors operated by this scheme of control and receiving full-line voltage. The current passing through the series field and the armature of each motor is indicated by solid arrows and the counter-electromotive force developed in each armature is opposite in direction and is indicated by the dotted arrows. Assume that these motors are running at full speed and that the controller is reversed, whereupon the connections in Fig. 8 are immediately established. The direction of current through the series field remains the same; the armatures are still rotating in the same direction, and, therefore, the direction of the counter-electromotive force remains the same; but the connections between the armature and the series field of each motor have been reversed, so that now the direction of the current through the series field and the direction of counter-electromotive force of each motor are the same. The series field and the armature are connected in a closed path, of which the resistance is relatively very low. If the starting resistor is designed to allow the passage of 50 per cent. overload at reversal, the counter-electromotive force developed in each armature is somewhat in excess of the line voltage. Each of the armatures may be looked upon as a booster assisting the line voltage to force current through its series field. The counter-electromotive force of one motor will probably be at least slightly greater than the counter-electromotive force of the other motor. For illustration, assume 250 and 240 volts from the top and bottom motors respectively. With this con-

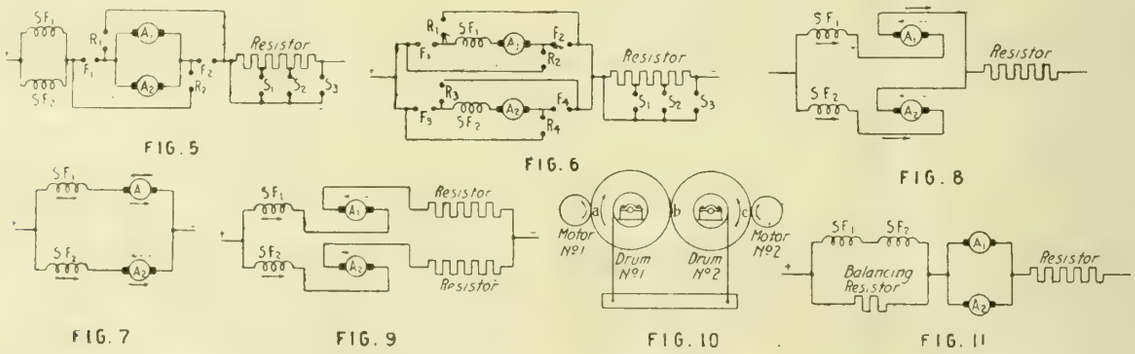
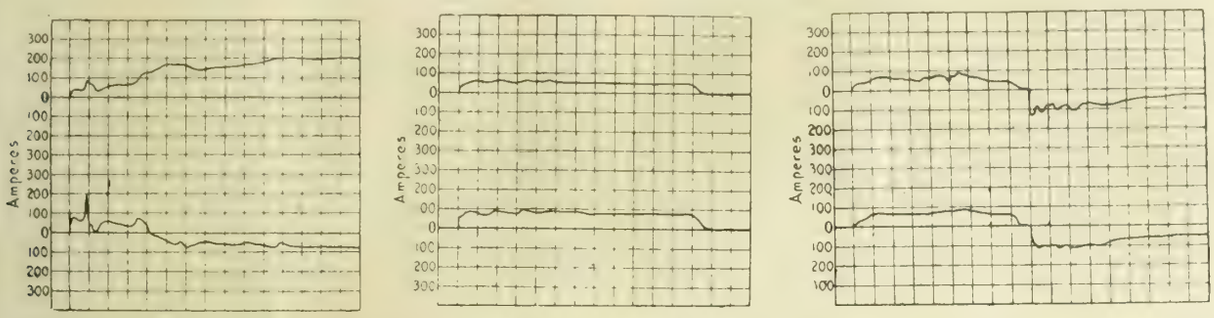


FIG. 5.—Control Arrangement of Two Series Motors by Single Controller. FIG. 6.—Control Arrangement of Two Series Motors with Single Starting Resistor and Separate Reversing Contactors. FIG. 7.—A Dangerous Arrangement of Series Motors. FIG. 8.—Another Dangerous Arrangement. FIG. 9.—An Improved Method of Controlling Two Reversing Series Motors. FIG. 10.—Arrangement of Two Mechanically-connected Motors on Ladle Crane. FIG. 11.—Method of Controlling Two Motors with One Set of Reversers and One Acceleration Resistor.

dition more current will pass through the series field of the top motor than through the series field of the bottom motor. The effect of this will be to further increase the counter-electromotive force of the top motor and further decrease that of the bottom motor. The fields become still further unbalanced, and presently, due to the predominance of the top motor, a local current circulates through the series field and armatures of the two motors, reversing the series field of the bottom motor. As soon as this is reversed, the direction of the counter-electromotive force of the bottom motor is reversed, and we then have two series generators in series with each other generating current in the same direction with no external resistance in the circuit. The result is, of course, an amount of current which is not only inconvenient, but positively dangerous. We therefore reach the conclusion that where only one acceleration resistor is used, it is advantageous to identify each series field with its armature in starting from rest, but that on rapid reversal these connections are dangerous, and should not be employed.



FIGS. 12, 13, and 14.—Speed Current Curves of Two 25-h.p. Series Motors on Bridge Motion of Crane, showing respectively Original Condition, Series Field Currents, and Corrected Condition.

The circulating currents described are prevented by employing the connections shown in Fig, 9. This differs from Fig. 8 only by having an individual acceleration resistor for each motor. The local path through which the circulating currents flowed has now been made to include such high total resistance that the circulating currents cannot get started, and with these connections rapid reversal is smooth and normal.

This analysis might be expanded almost indefinitely by investigating other more complicated methods of control, such as dynamic braking hoist controllers, armature shunts, &c. I will have to dismiss this additional subject with the statement that the more complicated forms of control contain even greater dangers of unbalanced loading and circulating currents.

Fig. 9, which has been reached by the elimination of all the previous diagrams, is, in my judgment, the only satisfactory way to control two or more mechanically-connected motors permanently in parallel. This diagram represents in reality a controller for each motor. In order that the controllers should function simultaneously, it is preferable to use two-pole contactors for two motors, three-pole contactors for three motors, &c. This assures that all important circuit changes, such as reversal or short-circuiting portions of the acceleration resistors, shall occur at the same time in each motor circuit.

Fig. 10 represents an interesting example of unbalancing, not of current, but of braking effort. This represents diagrammatically the hoist of a ladle crane, with the motors No. 1 and No. 2 permanently in parallel and geared, as indicated, to the hoisting drums No. 1 and No. 2. Each motor was equipped with a magnetic brake, but, due probably to unequal adjustment, one brake would act more quickly than the other after the cessation of current through its coil. Assume the ladle is being hoisted, in which case the motors and drums would rotate as indicated by the arrows. Suppose now that the controllers are brought to the "off" position, but that the brake on motor No. 2 locks the armature of that motor before the brake on motor No. 1 locks the armature of its motor. In this case the point *c* must remain stationary, but motor No. 1 exerts a force upward on the drum No. 1 at point *a*. This produces a downward thrust at the point *b* on drum No. 2, but as the mechanism is rigid in this direction, drum No. 2 does not move. The result is that drum No. 1 tries to rotate upward about the point *b*. The bearing caps, while of liberal proportions, were probably not designed to take an upward thrust, since it would appear that the weight of the ladle would always keep the drums resting heavily on their bearings. The final result was that the bolts holding down the bearing caps of drum No. 1 were stretched or broken. In this particular mechanism, if one brake locks before the other there is always a tendency to lift one of the drums, no matter which brake locks first, and no matter whether the load is being hoisted or lowered. This is an actual difficulty which has occurred in several instances, and I believe has led to the use of larger cap bolts.

Generally speaking, and within reasonable limits, the larger the motor the greater will be the number of acceleration contactors employed in the controller. For instance, in rapid reversing controllers, it is common practice to employ three acceleration contactors for a 50 h.p. motor and four for a 100 h.p. motor. With two mechanically-connected motors permanently in parallel, the question arises whether the number of acceleration contactors should be determined by the horse-power of the individual motors or by the total horse-power; or to put the question concretely, should three or four acceleration contactors be employed in the case of two mechanically-connected 50 h.p. motors. Probably the best way to find an answer to this question is, first, to decide why we use more acceleration contactors with large motors than with small motors. One reason is to flatten out the acceleration curve so that the current peaks will not be so large. A current peak of 175 per cent. on a 500 h.p. motor might cause serious line disturbance, whereas a similar overload peak of a 25 h.p. would be negligible as far as line disturbance is concerned. I think this point is more hypothetical than real in the case of the average motors employed in a steel mill as there is usually ample generator and line capacity. Another consideration is that a small motor generally commutates high current peaks better than a large motor.

Perhaps the leading reason for increasing the number of acceleration contactors on larger motors is to get a characteristic which it is hard to describe and which I will call controlability. It is usually satisfactory if a small motor accelerates from rest to full speed almost before the operator is aware of it, but in the case of large motors, operating heavy and important machines, the operator must have more sensitive and responsive control over the starting and reversing of the motor. Bearing these three thoughts in mind, it seems to me the number of acceleration contactors can be determined some-

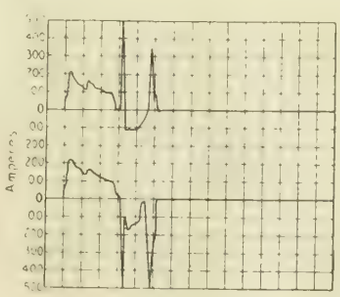


FIG. 15.
Speed Current Curves of Two 25-h.p. Series Motors controlled by arrangement shown in Fig. 6.

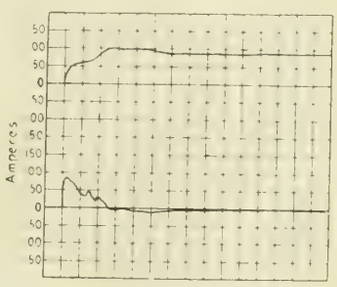


FIG. 16.
Speed Current Curves of Two 20-h.p., 230-volt Field Series Motors.

what in the following manner: If the motion is merely one of rapid reversal, and line disturbance need not be considered, select the number of acceleration contactors from the standpoint of the size of one motor; if the question of line disturbances is important, or if you are concerned with the controlability of the machine, select the number of acceleration contactors from the standpoint of the total horse-power.

There is time to discuss only very briefly a few of the many changes in the controller itself which have been suggested for the control of mechanically-connected motors in parallel. Fig. 11 represents a scheme for controlling two motors with one set of reversers and one acceleration resistor. The two fields are in series with each other and in parallel with a balancing resistor. This connection assures the same current in each of the series fields, but there is no assurance that the correct amount of current will flow through the series fields. In installing a controller of this kind cast grid resistors are generally used for the balancing resistor, having a cold ohmic resistance equal to the cold ohmic resistance of the two fields in series. During operation the balancing resistor and the fields both become heated, but the change in resistance will probably be unequal, inasmuch as they have different temperature-resistance coefficients and probably different current capacities. Consequently the series fields receive considerably more or less than half of the total motor current, leading respectively to overheating or diminished torque. It is almost impossible to divide the current equally, at all temperatures, between two low resistance paths in parallel.

When it is necessary to ensure uninterrupted operation of a machine driven by several motors some engineers have preferred an entirely separate controller for each motor rather than the two-pole or three-pole controller which I have advocated. They have argued that in the event of an overload, both motors were stopped with the double-pole method of control, but with separate controllers only one motor was stopped. As a modern controller can be reset in one or two seconds after operation of the overload device, I do not feel that this is a serious objection. Another argument has been that if a control circuit or an operating magnet failed on a double-pole controller, then the entire controller was temporarily useless, whereas with the same accident with two entirely separate controllers, the undamaged controller could be maintained in operation. There is some merit to this contention, but an argument against it is that there are just twice as many coils and control circuits on the two separate controllers as there are on the one double-pole controller. With two separate controllers there is no certainty that the important circuit changes will occur in each motor circuit at precisely the same time. There is danger, therefore, of unbalancing and of circulating currents, although it is true that these will exist for only a brief period of time. They constitute a menace, however, which, in my opinion, should weigh heavier as a possible cause of motor trouble than the two arguments which I have mentioned above as favouring the use of an individual controller for each motor.

If two motors are permanently in series, they, of course, require only the amount of current normally demanded by one motor of the same size. Each motor exerts full torque up to half speed, but at any greater speed the performance of two motors permanently in series is entirely different from the performance of two motors permanently in parallel. Two motors permanently in series will have a diminishing torque, whereas two motors permanently in parallel can maintain full torque up to full speed. This has sometimes been considered an advantage for roller table service. The line of thought has been that the important consideration is the reversing and acceleration up to perhaps half speed, and that it was a positive advantage if the motors did not have so much disposition to race if allowed to run in one direction for a considerable period of time. I have known of two or three mill tables where parallel connections were first tried for a while and where later series connections were substituted. By changing to series connections it was found that the motors did not race so much and that reversal was made easier. It was found, however, that the table was slowed down some, or, in other words, did not have as large a capacity to move steel. Of course, with motors permanently in series there is no danger of circulating currents or unbalanced load. The mechanical connection precludes the possibility of one motor reaching high speed while the other motor slows down, which would be a real hazard if the motors were free to run at different speeds. Therefore, from an electrical standpoint, permanent series connections must be regarded as satisfactory.

It is probably pertinent to give here a brief discussion of the controller for motors permanently in series. So far as its capacity to carry current is concerned, this can be decided from the standpoint of the size of one of the motors. However, the heating of the reversing contactors and the line contactor is due more to the arcing at the contacts than to the passage of current when the contactors are closed. The heat developed by an arc is largely determined by the persistence with which the current endeavours to flow when the circuit is opened. It is the inductive quality of the circuits to be interrupted which largely decided the severity of the arc at the point of interruption. In the case of a series motor, this inductive effect is represented mostly by the series field, and with two series fields in series, there results a much hotter arc than with only one series field. Therefore, it is erroneous to determine the size of arcing contactors for motors permanently in series from the horse-power rating of only one motor. Another consideration is the amount of resistors that must be supplied. If two motors in series reach full speed, and are then suddenly reversed, there is a voltage at the moment of reversal equal to the sum of the line voltage, the counter-electromotive force of one motor, and the counter-electromotive force of the other motor. Roughly speaking, this is about three times the line voltage, which demands more resistors for reversal than in the case of one motor.

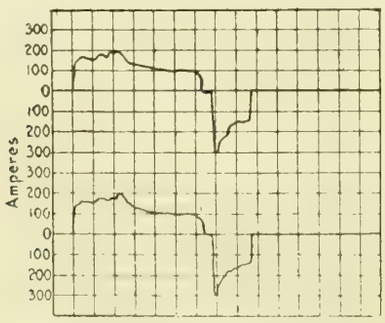


FIG. 17.
Motors of Fig. 16 controlled by arrangement shown in Fig. 5.

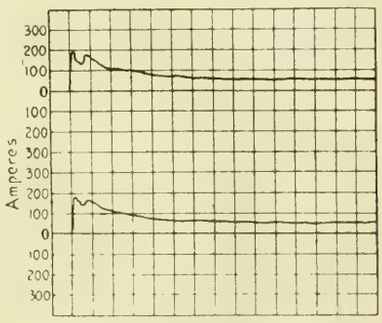


FIG. 18.
Speed Current Curves of Two 30-h.p. Series Motors controlled as in Fig. 9.

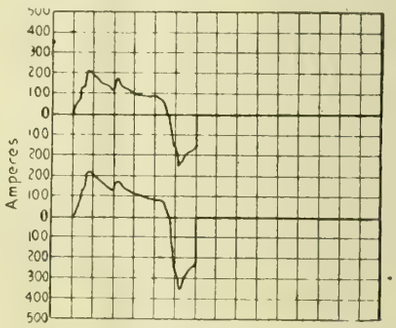


FIG. 19.
Speed Current Curves of Two 50-h.p. Series Motors controlled as in Fig. 9.

I have mentioned the belief held by some that it is easier to accelerate two motors than one motor having a rating equivalent to the sum of the two motors. I have made a rather thorough investigation of mill-type motors to determine in a variety of cases the time required to accelerate the armature from standstill to rated full load speed, supplying the motor with the usual acceleration current. Although in some cases the moment of inertia of the armature increases more rapidly than the horse-power rating, yet this is more than overcome by the fact that the normal full-load speed is less in the case of the larger motors. I cannot find any support of the theory that a small motor can be accelerated to full-load speed more rapidly than a large motor, assuming in each case the usual acceleration current and taking account of the fact that the normal speed of large motors is less than that of small motors.

I am able to present a number of current curves of two

mechanically-connected motors permanently in parallel; these records were made by a double-recording ammeter built specifically for this investigation and capable of indicating graphically the simultaneous variations of current in two entirely separate circuits. So far as I know they are the first curves of this kind which have been made. Each figure shows the current changes in the two different motors, and for brevity I shall refer to them as the top and bottom motors, meaning thereby the motors the curves of which are shown respectively at the top and bottom of the figures.

Fig. 12 represents two 25 h.p., 230-volt series motors operating the bridge motion of a crane having a 116ft. span. The controller is identical with that shown in Fig. 5; in other words, there is one set of reversers, one acceleration resistor, one set of acceleration contactors. The fields are permanently in parallel, and the armatures are permanently in parallel. To our surprise we found that the current in the top motor rose to 200 amperes, whereas the current in the bottom motor actually reversed and reached a value of 80 amperes. The bottom motor, therefore, was acting as a generator and was retarding the motion of the crane to the extent of 20 h.p. In other words, one motor alone would drive this crane faster than the two motors in parallel. It was surmised that this condition was due to unequal currents flowing through the series fields, and the instrument was connected to measure the currents in the series fields.

The results of this investigation are shown in Fig. 13, from which it can be seen that the series field current in the bottom motor is about 50 per cent. larger than that in the top motor. To correct this unbalancing, additional resistance was placed in series with the field taking the largest current, making the division of current as nearly equal as it was possible to do with the means at hand. Fig. 14 shows the motor currents after the fields had been equalised. One motor takes about 60 amperes running current and the other about 40 amperes, but by comparison with the conditions shown in Fig. 12, the installation could be regarded as fairly satisfactory. The current, at least, flows in the same direction in each motor. Fig. 16 relates to two 20 h.p., 230-volt series motors driving another machine. The controller was the same type that was used in the previous test. When acceleration was completed, the top motor took 90 amperes, whereas a small current of about 5 amperes passed through the bottom motor in the reverse direction. This particular machine has been running in this way for two or three years, and if anyone had remonstrated about this type of control, probably the answer would have been that inasmuch as it continued to run, it was all right. Within the last few months, however, the motors have given serious trouble, and it will soon be necessary to replace them. The point which I wish to emphasize is that these two motors would have had a liberal surplus of capacity had they been controlled in a correct manner. They were originally made larger than seemed strictly necessary in order to provide just this capacity for emergency, but due to the poor method of control, one of the motors was made to take so much current that there was no safety margin left. In other words, if one of two motors takes much the larger share of current, no doubt your conservatism in selecting motor sizes will enable this equipment to operate for some time, but you have removed that emergency capacity which you intended to have and which would undoubtedly have resulted in longer life and fewer interruptions to service.

Fig. 15 relates to two 25 h.p. series motors regulated by a controller of the type shown in Fig. 6; in other words there are individual reversers for each motor, one acceleration resistor, one set of acceleration contactors, and each series field is connected to its armature. I pointed out previously that this type of control is satisfactory for acceleration from standstill, but at the moment of reversal heavy circulating currents come into existence. Fig. 15 is a striking confirmation of this theory. The acceleration is satisfactory, but at reversal the bottom motor reverses the polarity of the top motor and a circulating current of at least 500 amperes flows through the two motors in series. There is a peculiar diminishing of this current shown on the curves with a subsequent re-establishment of a somewhat smaller circulating current. I am unable to explain this, but it may be due to surges or it may be that the operator pulled the master switch to the "off" position and then threw it back again. This does not matter, however, the important point being the existence of the heavy circulating currents. An attempt was made to correct this difficulty by connecting an equaliser from the junction of the series field and armature of the top motor to the junction of the series field and armature of the bottom motor. This was merely a reversion to the type of controller shown in Fig. 5, with the fields permanently in parallel and the armatures permanently in parallel. The danger of circulating currents on reversal was removed, but the division of load was not good, the results being indicated in Fig. 17.

Figs. 18 and 19 show the operation of what I consider the correct method of control. The connections are those of Fig. 9, which include for each motor individual reversers, an acceleration resistor, and a set of acceleration contactors. The controller is made up of two-pole contactors throughout, one pole of each contactor being in one motor circuit and the other pole being in the other motor circuit. Fig. 18 shows the acceleration of two 30 h.p. series motors. Fig. 19 shows the acceleration and reversal of two 50 h.p. series motors. There is little comment to be made on these curves except to say that they are all right. The currents during acceleration, reversal, and during normal running are almost the same in each circuit; each motor is doing its fair share of the work, the only uneven division of load being due to imperfections in the motors themselves.

METHOD OF REPAIRING OPEN-HEARTH REGENERATIVE FURNACES WHILST IN WORK.

A PATENT recently granted to the Clyde Furnace Company, Ltd., 116, Hope Street, Glasgow, relates to the repair of blocks of regenerative open-hearth furnaces whilst the furnace is working, the object being to provide, in conjunction with the centre, means whereby the plastic material may be supported at the front whilst in the plastic state and until it has properly set and hardened. A steel or iron plate is employed, which is let into a slot or cross-cut at the top of the centre.

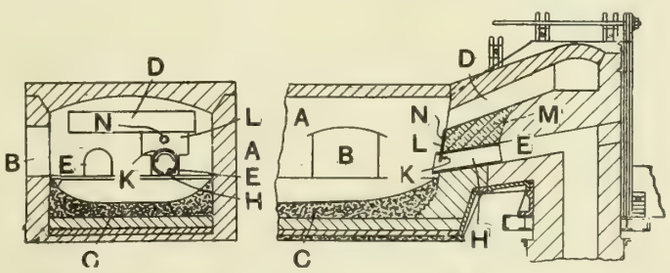


FIG. 1. FIG. 2.
METHOD OF REPAIRING OPEN-HEARTH REGENERATIVE FURNACES.

The slot is made before the centre is inserted into the furnace, and the plate is inserted into the slot after the centre is in position in the furnace. Fig. 1 is a vertical section of part of a furnace, showing the centre as provided with retaining plate for supporting the plastic material at the front thereof, and Fig. 2 is an internal view of part of the furnace, showing the centre with its retaining plate in elevation. A is the furnace, B a furnace door, C the working bed or hearth, D the air port, E a gas port, and H the centre. The centre H, which is made of metal, has an inclined slot K made in it, and into this slot a retaining plate L is inserted. As will be seen this plate lies at a suitable angle (usually the angle of the face of the block), and forms a support for the plastic material M, which is filled in at the back thereof and on top of the centre. By the time both the centre and the plate are burned away the refractory plastic material has solidified and is left in position. The plate L is furnished with a hole N for purposes of manipulation.

Fatal Boiler Tube Failure.—According to "Power," one of the second bottom tubes in a 500 h.p. water-tube boiler at the Fisk Street Station of the Commonwealth Edison Company recently burst while carrying full load. Four men were scalded seriously, one who was working the fire at the time succumbing to his injuries a few hours later. The boiler was one of a battery serving a 12,000 kw. turbo-generator. The unit had been placed back in service only about six hours before the accident, after having been shut down for its annual overhauling.

THE ECONOMIC OUTLOOK AND THE LABOUR PROBLEM.*

BY F. W. LANCHESTER.

THERE are many who will deny that life is any easier to-day than it has ever been; in fact prior to the war it was the fashion to speak of the strain and stress of modern life and the hard conditions which the modern worker has to face, as if for centuries things had been going from bad to worse in that respect. I will take one example as bearing on this point as food for thought, a 2lbs. loaf of bread, and I will take it at its present war price, say, 6d. At this value a loaf of bread represents an hour's labour for a poorly-paid artisan, it represents half an hour's labour for a well-paid artisan, it represents 10min. or a quarter of an hour's labour for many a present-day skilled worker in munitions factories, it represents about two or three hours' work for a woman employed on what I believe it is the custom to term "sweated labour."

A plough is an engineering implement, a windmill is an engineering appliance: we may accept both, we will not go back in our comparison to archaic times. Where is the superman who could dig sufficient land, sow sufficient corn, cut it with the old sickle, thresh it with the old flail, mill it, and go through the whole process of leavening and baking by the appliances of but a century ago and produce loaves at the rate of one per 10min. or quarter of an hour? Where is the ordinary man who could produce loaves under these conditins at the rate of half an hour labour each, and where is the community who, even with the comparatively modern appliances granted, could produce their daily bread at the rate stated, and at the same time carry on a great fight for their existence? When we consider that the war price of the loaf above stated is double the normal price, which represents only about one and a half hour's work of the so-called sweated woman employé of an East End clothing factory, we realise what the engineer of the past, coupled with the trade organisation which his work has rendered possible, has done for humanity, and we realise how ill-informed and how meretricious is the cry of the stress of modern life. It is not as if the conditions applied to the loaf alone, but almost every other necessity of life has been similarly cheapened. The time of labour which it takes to support per head of population at the present day for a given standard of living for the necessities of life, and even including what may be legitimately termed luxuries, has been lower during the last 50 years than it has ever been in recorded history.

The truth is that attempts have been made by the natural ambition of the human being and the well-meant efforts of social reformers to push up the standard of living faster than the means available, and this has been accentuated by the false views on matters of economics which have been held, or at least advanced, by the leaders of trades unions and by one at least of our great political parties. This advance in the standard of living is, to a certain extent, legitimate, and wholly to be commended; but it is, unfortunately, to a great extent, competitive. The dissatisfaction of Jones is not so much because his health or that of his family is suffering from shortage of food or other necessities of life; it is not so much because he cannot have his little luxuries and amusements from time to time, or that he cannot afford an annual holiday spent by the sea; it is not because Mrs. Jones or the little Joneses are not adequately clothed from a hygienic standpoint. It is because the Smith family, his neighbours, in all these things are just a little better off than himself, and this applies from the highest-but-one rank of society down to the chimney-sweeper. Beyond this the social reformer, who often has lived a life of comparative ease and affluence, wishes to impose on others conditions which become too great a strain and burden on the collective resources of the community.

Now it is the opinion of nearly every employer of labour with whom I have had the privilege of consulting that the standards of living at present existing and embarked upon are economically possible for the various classes concerned, provided that the worker does not cut down his hours per week and co-operates loyally with the employer in producing the maximum output for every hour's work. I have also heard the opinion expressed, and that in very well-informed circles, that the labour leaders after the object-lesson of the war in the cutting down of costs and increase of output, realise fully that the old restriction of output policy was a mistake and detrimental to their best interests; and, further, that no question will ever arise again of restricting output as part of a trades union policy. Let us hope in the interests of the rank and file of labour and of the whole country that this is so.

I have had no personal contact with the leaders of the men's organisations myself, and I confess to being not too sanguine as to the future. Even if the facts are as stated so far as the leaders are concerned, it is by no means certain that the men will follow. Let us study the facts, firstly the economic facts, and then the facts of past history. The fundamental fact from an economic standpoint is that if one man were, like Robinson Crusoe, alone on a desert island he would be able to consume what he produces and what he can persuade nature to help him in producing, no more. If two men were on the desert island they likewise could consume what they jointly produce and no more; so with three men and four men. Without doubt the greater the number of men (within the limits of acreage) the more individually they may consume, because by dividing up the work they would be able in some small degree to increase their power of production; but whether one, or four, or a dozen, they would be continually alive to the fact that the longer hours they work and the harder they work the greater would be the product of industry and the better would be their standard of living. There would be no illusions on this subject, and if one of our claptrap orators were to be dropped amongst them to tell them they would be far better off if they would work shorter hours and restrict their output, he would be received with well-merited derision. Yet the same fundamental facts apply no less forcibly to an actual community whatever its size may be. The total consumption, and consequently the individual standard of living, is finally limited by the total production, and can only be diminished, and never increased, by restrictions on output.

Now let us examine the means by which production can be augmented, that is to say, how the output of labour may be increased. There are two main agents—(1) Knowledge, (2) Implements. In the primitive community we see the value of knowledge in all the crafts and devices of primitive nations, methods of making fire, methods of trapping animals, &c. Alongside of this, knowledge enters into the methods of making and using their rudimentary implements, &c. There is no real distinction in this respect between the primitive community and the most highly civilised, the two factors are still knowledge and implements, the difference is quantitative rather than qualitative. An advance in knowledge alone may be a means of increasing the output per hour of labour. Under the broad heading implements I include for the present purpose everything from the roof over our heads and the cloths that we wear, to the agricultural and industrial machinery which we operate, and the nets in which we catch fish. The engineer is in a sense an apostle of knowledge and a designer of implements. His business in life is to seize on knowledge, incidentally he may add to the sum of knowledge and apply same to the sum and total improvements of implements.

Now the product of the engineer, implements, is (apart from the direct application of knowledge) the great means by which the product of an hour's labour may be increased. Thus a man with a pointed stick can prepare a certain area of soil for sowing in an hour, but a man with a spade can prepare a greater area, and a man with a plough a greater area still. Similarly in the problem of transport a man can carry a certain load on his back, he can carry a greater load on a wheelbarrow, and a greater load still with a motor lorry. All this looks like platitude, but we have to remember that if it is platitude, then the British working man's folly must be accepted as self-evident, for as long as the history of manufacture goes back he has strenuously opposed the introduction of new and better implements. We know how long his opposition was felt in the cotton spinning and weaving industries; and we hear of this kind of opposition again at the time of the great engineering lock-out in the nineties; even to-day prior to the war the old difficulties were cropping up as to whether the trades unions would allow one man to work more than one machine, although the said machines were designed almost to work themselves! Also the artificial restrictions of output

* Abstract of presidential address delivered before the Junior Institution of Engineers, December 11th, 1916.

such as were in full force both openly and otherwise at the time of the outbreak of war were a direct negation to the whole principle on which the introduction of labour-saving machinery is based.

But we can go still deeper into the matter. Implements of any kind cannot be created they have to be made; and every implement represents in its manufacture a certain amount of unrequited labour. There is the direct labour, the work of the artisan and the unskilled labourer in producing and assembling the parts, and the labour (once removed) in the value of the material. There is behind that the work of an engineering staff applying existing knowledge to the best advantage, namely, as in the design of the implement and the study of its economic production. There is also the labour of the men who are responsible for, and who form, the organisation. These latter are commonly included as "dead charges," but the sum and total of the labour is represented according to the standard of coinage of the country as some certain sum of money, just as the weight of the machine is represented by a certain number of arbitrary units of mass. In other words, the value in £ s. d. is a measure in arbitrary units of labour. The labour required for supplying the community as a whole, *i.e.*, the nation, with implements during any period has to be deducted from the sum and total of labour over the period concerned.*

Thus the implements of a self-contained community are definitely the savings of the community over the period during which they are produced, and when we hear that the accumulated wealth of the United Kingdom has increased £10,000,000,000 sterling in the last half century, that £10,000,000,000 sterling is visible around us, it is in the main what anyone who has lived long enough to take stock of things for half a century may see, in the growth of the "implements" by which the product of labour is enhanced and by which the comfort and standard of living have been augmented.

There are many who would be inclined to question the need for the continual change and advance which may be almost described as the spirit of the times; doubtless there are strong arguments which could be urged against the too rapid change of environment of the race, for that is one unquestionable consequence. A great many of our bodily ills, and certainly many of our social evils, are clearly attributable to this rapid change in environment and corresponding changes in the conditions of life and mode of living. However, in the face of facts, opposition is futile; a State or nation which does not keep abreast of the times ceases to be in a position to offer proper protection or support to its citizens. Such is the teaching of history. It is useless to question the policy of advance in industrial matters. One lesson of the present war is the comparative impotence of a nation whose industries are not in a flourishing condition. The strength of Britain to-day, and the strength of our most redoubtable enemy, Germany, lies as much in the industrial strength of the respective countries as in the military prowess of the men in the field. Thus, apart from the necessary peace-time expenditure in arms and armament and the maintenance of an Army and Navy, a State must devote a large proportion of the product of its labour to the increasing of its accumulated savings, or capital, or sooner or later it will fall.

It has ever been one of the obstacles to the improvement in the position of the artisan and other manual workers in this country that his savings as a class relatively to the nation's needs are small. Enquiry made of some of our big industrial firms as to the position, even now during war time, with wages at an abnormally high level, is disappointing. Under encouragement of every kind, with an automatic savings scheme, including a bank on the premises, the savings do not amount to more than about 5 per cent. of the total wages; and if this is the case under present conditions with the patriotic incentive, one realises that under normal conditions the proportion is lower. It is, in fact, far lower. There are many who would suggest at once that if you want a man to save more, you must give him more; but unfortunately human experience does not bear out this view. Even the working man's organisations, the big trades unions, have no permanent capacity for saving; it is true that the funds frequently rise steadily over a long period and may run into six figures, but it is almost possible to predict when labour troubles are due from this very accumulation of wealth. When the amount of the funds in pounds sterling reaches the number of men multiplied by five, it is almost certain there will be trouble. One might term that figure the strike point. I have talked with men on the subject, and I have heard many views expressed by the working man. His feeling is that the money of his trades union invested in ordinary securities, such as railways, bonds, &c., is doing nothing; in other words, the interest which is accruing is not considered a commensurate return for the self-denial which it has required to accumulate the fund. Neither can we look to the Government as a source of saving, since no modern Government has shown any capacity in that direction, whether democratic or autocratic; the National Debt invariably exceeds the State's productive assets.

According to present experience, then, the saving power which is essential to the welfare of the State belongs to a minority. It is not an unchangeable minority—in other words, a hereditary financial group or an oligarchy—since it is continually being recruited from the ranks; any industrious man who likes to join does join. In spite of this the change and renewal is gradual and slow; it may be broadly stated as an axiom that the man who saves is the man who has saved, and consequently the main savings of the country will be derived from its trade and industrial dividends and other revenues from investment; hence, broadly, the saving power of a country will be a measure of its dividend-earning power.

The manner in which in the past organised labour has set itself against efficiency in production in face of the fact that restricted production is an obvious economic fallacy, denotes something more than is apparent on the face of it. The views have been so stubbornly held in the past that, in spite of piece-work and of various forms of bonus system, even worked on a broad-minded and liberal basis, deliberate restriction is still continued. A typical instance came under my notice just prior to the war. A certain article had been produced in a works in which a bonus system was in force on a turret lathe with a well-devised outfit of tools; but the cost was persistently too high. There was bonus to be made by lowering the price, but batch after batch went through, sometimes in one shop and sometimes in another, but no improvement was secured. That same job went, by accident, owing to pressure of work, into the tool-room, and a batch was put through by a tool-maker on an ordinary engineer's lathe, with an actual saving of money. Such cases are by no means uncommon. Here the work of the industrial engineer has been entirely negatived by the systematic and organised restriction of output, in spite of every attempt at encouragement.

With the existence of the country at stake, if we may say so, and with a special Ministry created to stimulate and control production, these conditions have been largely overcome; and to-day, without question, a large majority of skilled and semi-skilled labour in this country is doing its loyal best to produce as much as possible. If this state of things can be perpetuated after the war there is hope that, not only can the pre-war standard of living be maintained (in spite of the need for an increase in the annual expenditure as due to obligations contracted during the war), but it may perhaps be improved. We may possibly even have a bigger margin than ever before, after allowing for the payment of both interest and sinking fund on the National Debt with which we shall then be saddled. The whole question is whether organised labour can be persuaded to take the view which its own interest, as well as that of the State, requires.

I confess that the outlook appears not too hopeful. Every concession hitherto obtained from organised labour has been under a Government pledge that the old conditions will be restored after the war. This fact alone shows clearly that labour as a whole has not yet learnt its lesson. But one is credibly assured that both members of the Government and the men's leaders realise the importance of continuing the accelerated production after the war as during it. Assuming this to be true, it is by no means certain that the difficulties are at an end. We have seen again and again the men's leaders enter into an agreement which the men themselves will not honour, and it is difficult not to believe that (unless the men themselves are brought to see the necessity of what

* Here we strike once again one of the fallacies of the working man's advocate; he wants to know why in the name of justice the working man cannot consume (in equivalent) all that he produces.

the future demands) they will feel, if the Government and their leaders do not carry out the pledge to restore the old conditions, that they have been in some way tricked or imposed upon. Considering that the position of the leader depends almost from day to day upon the support he receives from the rank and file, I cannot but feel that the future is by no means assured.

It is clear beyond the need for argument that if the attitude of labour in this respect is unsatisfactory, nothing that it is humanly possible for the employer to do can prevent serious dislocation. When all is said and done, the employer, be he an individual, or managing director, or general manager (acting under a board of directors), is, in his function of regulating wages, a "pressure centre" on which a number of forces operate. He has to manufacture some commodity and sell it. When he can add up his costs of various kinds, and they come within the price at which he can sell his output, he can conduct business. The claims of the shareholder are the last to be met. Provided that the employer pay his men, and pay for his materials, and his rent, rates and taxes, gas, water, &c., and his office and technical staff, he can sell the goods. If there is no margin, the shareholder is the first man to suffer. But, broadly speaking, the shareholder must be paid like everybody else; on him the existence of the company depends, for, if he is not paid, the particular company may find itself at any time in financial difficulties; it is unable to raise money if the conditions of trade necessitate a heavy expenditure in maintenance or an increase of capital. But, beyond this, the existence of an undue number of industrial concerns in the country paying no dividends makes investors shy ("Once bitten, twice shy"), and home industrial investments become unpopular; it becomes impossible to find further capital, and employment stagnates. Thus, as a general fact throughout the country, the shareholder must be paid. Suppose that labour demands a higher rate of pay. Let the employer grant the higher rate, he has at once to put the cost of manufacture up and to ask a higher price; the whole thing is quite automatic, and so the manual worker (to-day the biggest consumer for many commodities) having obtained higher wages, finds that he has to pay a correspondingly higher price for his goods. That is the working of the economic law in detail.

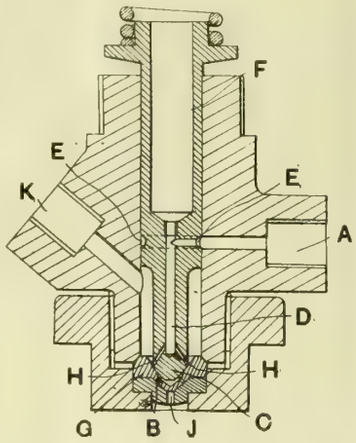
Here it may be pointed out that if, broadly, throughout the country, the hours and the intensity of labour remain the same, but by demands on the employer the wages are put up all round, the automatic effect is that the cost of living goes up roughly in proportion and the conditions remain just as before—cheques carry higher figures than previously, and the coinage circulates a little more rapidly, with no net benefit to anybody, and equally with no fundamental economic loss. When, however, the demand of organised labour takes the form of a reduction in hours, without any compensating increase in the intensity of labour, then the standard of living must go down, that is to say, below what it would have been otherwise, for since the output per man is less the consumption per man must be less. You cannot eat your pudding if you don't make it—a variant of an old proverb. A reduction in hours may be compensated by an increase in the percentage of workers, such as when women enter the factories in greater numbers, the standard of living being thus maintained, but such recruiting of industrial labour in this way cannot be carried beyond a certain point without detriment to the health and welfare of the State. Already many of those who look ahead see national danger in this very cause—our vital statistics already give some indication. The danger of artificially limiting the hours of men's labour, as tending to throw upon women the onus of becoming breadwinners to an extent prejudicial to the national welfare, should be borne constantly in mind by statesmen and economists. The shortening of hours may be more legitimately compensated for, as already stated, by increased intensity of labour: it will probably always be a question of debate what is exactly the best number of hours to be worked in each different trade from the point of view of economic production.

(To be continued.)

The Minister of Munitions has appointed a Committee under the chairmanship of Mr. C. W. Fielding, to advise him upon the steps which can be taken to secure the most economical use of the metals required in the manufacture of munitions of war.

FUEL INJECTOR FOR OIL ENGINES.

THE accompanying sectional view shows a design of fuel injector for internal-combustion engines, the invention of Mr. Edward Gardner, Barton Hall Engine Works, Patricroft, Manchester, of the type which delivers two fuels, one a readily-ignitable fuel for ignition purposes, and the other a less readily-ignitable fuel for power purposes, the former fuel being delivered slightly in advance of the latter. An inlet port A for the ignition fuel is provided in the injector body. The injector control valve C is provided with a fuel passage D, co-axial therethrough, which receives its fuel supply from the inlet port by way of a peripheral groove E around the piston portion F of the valve stem, and which delivers its fuel into the valve seating ring G through a plurality of radial downwardly-inclined passages H, terminating on the inlet side of the valve seat. The upper surface of the valve seating G tapers sharply downwards as shown, so that when the valve is opened by the fuel pressure in the ordinary manner, the downwardly-projected ignition fuel jet or jets coming from the valve will issue into the ring and be directed towards the apertures B leading to the tangential grooves, whereby the fuel is given a swirling motion as it issues from the aperture J. The arrangement of the ignition fuel passage D ensures that such fuel issues the first from the injector without being dispersed into the injector body, where it may become mixed with the power fuel entering by the port K. The ignition fuel is thus more efficiently utilised than heretofore, with a resulting economy in the consumption of such fuel.



FUEL INJECTOR FOR OIL ENGINES.

DESIGN OF SUBMARINES.*

BY CAPTAIN W. L. RODGERS, U.S.N.

SOME years ago I was president of the Naval War College, and ever since I have given attention to the strategic and tactical fields of work which are open to submarines in naval warfare. A sketch of these fields and a consideration of possible modifications and variations in design of submarines to meet the requirements of warfare seem to me to offer interest to naval architects, and it is along these lines that this paper will be developed. In thus discussing the subject, it must be borne in mind that while the constructional and engineering possibilities of design are pretty well known, and form a stock of knowledge common to designers of all nations, nevertheless the application of this stock of knowledge to the production of concrete designs suitable to the national policy and geographic situation of particular nations will result in types of ships which will differ much according to nationality.

The purpose of this paper will be first to examine the peculiar military characteristics of submarines in general and compare them with those of other types of combatant ships; second, to consider how these general characteristics will influence or control the employment of submarines in war; and, finally, what particular types of submarines seem best suited to American needs.

Submarines are armed with torpedoes and with guns. Owing to the great percentage of the displacement which is necessarily devoted to the heavy hulls and very heavy machinery installation, the speed of submarines is much less than that practicable for surface craft of the same size. Conse-

* Paper read before the American Society of Naval Architects and Marine Engineers, November, 1916.

quently submarines, unlike torpedo boats and other fast craft, cannot rely on their speed as a means of safety. For the submarine the chief means of defence is provided by her submersibility and consequent invisibility. Further, the great weight of storage batteries forbids giving submarines more than a small radius of action when submerged. The submarine obtains information only when able to see—at the surface. She can navigate freely, and recharge her storage batteries only when running the oil engines at the surface. These are the chief peculiarities which affect the combatant powers of submarines. They affect alike those submarines which are armed with torpedoes and those of that other type, the fruit of the current war, which are designed as mine layers. Bearing these peculiarities in mind, we may proceed to consider the general principles which these qualities require a captain to observe in the employment of a submarine under his command.

In regard to the torpedo, a peculiarity exists which differentiates its use very much from that of the gun. The initial velocity of a projectile from a high-power gun is 3,000ft. per second. The speed of the fastest ship is not over 60ft. per second. As these two velocities are in the ratio of 50 to 1 a ship cannot escape from a projectile fired at her. The greatest velocity of an automobile torpedo seldom exceeds about 40 miles an hour, and this only for moderate ranges. By reducing the speed to 30 miles or less an hour the compressed air in the flask can drive the torpedo further, but such speeds are of the same order of magnitude as those of the target ship. Consequently, the direction and speed in which the target ship is moving are most important elements in deciding when she is within range. Consider, for instance, a 30-knot torpedo capable of running 10,000 yards. If fired at a ship approaching at the rate of 20 knots there is a chance of hitting if fired at a distance of over 16,600 yards, whereas if the target is withdrawing at 20 knots the torpedo will exhaust its motive power and stop before overtaking the target if fired from any range above 3,300 yards.

When submerged the submarine itself also is limited both in speed and radius—12 miles at most at 10 or 12 knots, 100 miles, more or less, at 5 or 6 knots. Thus when submerged the submarine's area of action resembles that of the torpedo which it carries as its chief weapon. It cannot chase to advantage when submerged. We cannot give a submarine the highest surface speed because of the heavily built hull and the heavy storage batteries. Such surface speed as we are able to confer on a submarine is inadequate for the tactical requirements of battle. It may enable a submarine to assume a favourable position for submerging ahead of an approaching enemy, but it cannot be great enough to be satisfactory in the tactical approach, as is the case with the torpedo boat at 30 knots, which relies upon her great speed as a means of protection when charging upon the enemy. As the submarine when submerged cannot hope to overtake its target it must lie in wait for the target to come to it.

Thus limited to moderate surface speed and low submerged speed, and unable to increase weight by the addition of armour, the submarine is obliged to rely upon her faculty for concealment as her chief means for employing her weapon, whether mine or torpedo. But concealment entails disadvantages. In hiding herself she becomes blind, and if by the adoption of the periscope she has recovered partial sight, she has sacrificed a corresponding measure of invisibility. Before concealing herself to attack, the submarine first must sight her enemy in order to direct her attack. To accomplish this to best advantage she must rise and search the horizon with natural vision. Unfortunately when so doing she cannot promptly submerge, and is therefore liable to surprise attack. The submarine's difficulty in seeing has consequences which extend beyond the individual ship. In warfare there is a combatant advantage in superior numbers which is greater than the numerical ratio of the hostile forces (as may be mathematically shown). For this reason it has always been reckoned a great point, both ashore and afloat, to bring superior forces to engage simultaneously upon the field of battle. But the submarine's imperfect vision occasions danger of interfering with friends when large submarine forces are concentrated for simultaneous concerted action, such as does not occur in the assemblage of any type of surface craft. Thus the submarine is not only an arm to be used by stealth, but its most favourable opportunities occur in dispersed and solitary action rather than in concentrated and co-ordinated action.

Having thus glanced at the offensive and defensive capabilities of submarines, we may now turn to the means of parrying their attack and of overcoming it. Until the outbreak of the current great war there seemed to be no adequate defence against submarine attack, but necessity is the mother of invention in tactics as well as in material, and there is less to fear from the submarine now than at the outbreak of the war. The great ships which the submarine would most gladly meet find their best protection is rapid motion; for the slow submarine, seeing imperfectly, is disconcerted by swift movement, more especially if this is accompanied by frequent alterations in direction. But ships cannot be always on the move, and it is necessary to provide both passive defence and active counter-attack against submarines. For harbours and certain sea areas the passive defence is furnished by wire nets, whose meshes are of a size suitable for catching submarines, while the counter-attack is made by thousands of swift patrol boats whose business is to destroy the submarine or force him down again whenever he comes to the surface for information or for air to start his engines and to recharge his batteries.

The success of these measures against submarines is undeniable. At the beginning of the war German good fortune with submarines promised the most important results, but as the war drew on the efficacy of submarine warfare diminished as methods of reply to it developed. It is now an important arm, but not the supreme one. By a line of *a priori* reasoning the general broad conclusion to be drawn from this survey is that the submarine is essentially a defensive arm, whose use as an offensive arm, although practicable, yet partakes somewhat of the nature of a *tour de force*.

After this brief review of the general qualities of submarines and the probabilities open to them, we are ready to take up the consideration of the particular types of submarines best suited for American use. Preliminary to this examination it will be desirable to summarise the accomplishments of the submarine under the conditions imposed by the relative situations of the present belligerents.

The early performances of German submarines caused them to stand very high in popular estimation, but they have not yet been able wholly to justify the expectations they first aroused. The efforts of Germany to wrest the control of the sea from the grasp of Great Britain and her Allies called for the exertion of the highest type of offensive war; but, as we have already seen, the submarine, in its essential nature, is the defensive weapon of the weak. It met with a temporary success, first in the North Sea and later in the Mediterranean, which in each case lasted only until the Entente Allies had time to prepare counter measures. At the opening of the war British ships advanced boldly to the German side of the North Sea and manœuvred there at slow speeds. The hostile submarines took advantage of their opportunity, and the British forces withdrew from the vicinity of the German coast. Great Britain then developed the net defence of her ports and of the cross-channel routes to France, as well as the counter-attack against hostile submarines and mine-layers by the patrol flotillas, of whose work such an excellent idea is given in Kipling's "Fringes of the Fleet." After six months of warfare the Germans began their submarine attack upon commerce. The strategic features of this phase of the war need our consideration.

German submarines were charged with the aggressive task of destroying commerce, but owing to their essentially defensive nature they were obliged to lie in wait in positions where shipping would come to them. The favourite area was that between the south of Ireland and the western entrance of the English channel, since nearly all British foreign commerce naturally took that way. But as the Straits of Dover were protected by nettings the Germans were obliged to pass around the North of Scotland to reach their station, a distance of about 1,200 miles. Once there, it was necessary to lie on station some days in order that the time at work might be in reasonable proportion to the time needed to make the trip and return. Thus, as a matter of logistic economy, the submarine employed on this service required a large radius of action, which entailed a considerable size—about 800 tons. Our atten-

tion has been particularly centred on these large craft because their deeds attracted most notice, but they are not the only ones employed. We have every reason to believe that, where submarines are needed for their proper defensive rôle to protect the German coasts, much smaller ones are used. Similarly, the English—who have the mastery of the sea, yet need submarines to aid in the protection of their ports against sudden raids—make use of small ones. So far as we know, submarines have accomplished little or nothing during the current war when acting in company with the main fleets. At the Battle of Jutland last May they seem to have been absent or ineffective.

The evidence of the present war as to submarines may be summarised by saying that on both sides they have obtained a degree of success in defence, to the extent of forbidding the approach of the main fleets of both sides to hostile coasts. In this successful coast defence submarines have been greatly aided by mines.

The use of submarines for the purpose of strategic attack has been less successful, although Germany's attack, in particular, has arrested much attention. The submarine strategic attack has been chiefly directed against commerce, by the British and Russians in the Baltic Sea against German trade with Sweden, and by the Germans at the entrance to the English Channel against the ocean trade of France and Great Britain. While this destruction of commerce has been serious, it has not led to conclusive results, although the narrow waters in which this contest has taken place have been favourable to the efforts of submarines because commerce has been obliged to cross the areas infested by them.

In estimating the value of submarines in the current war we must not attribute the present shortage of commercial shipping wholly to the deeds of submarines. In the order of their importance the factors in this shortage seem to be: First, the great military and naval demands made upon commercial shipping; second, the internment at home or abroad of all or nearly all shipping of the Central Powers; third, the delays imposed upon Allied shipping by the patrol and mine-sweeping services, which have adopted a retardatory but necessary administrative system for the protection of ships passing through dangerous areas; fourth, the actual loss of shipping caused by submarines, which seems to have been about 3 per cent. a year, more or less, nearly the same the English merchant service encountered without serious consequences in the Napoleonic wars.

The foregoing discussion has had the objective of placing us in a position to consider what type of submarine will best suit the requirements of our own navy, and this we shall now proceed to do. The geographic situation of the United States, with a very extended coast-line, much of which is remote from possible enemies and borders great oceans, is very different from that of the present combatants, who are separated by comparatively narrow waters and confront each other at relatively short ranges. As we have seen, the submarine is essentially a defensive arm. It finds least opportunity when it meets its enemy in the open sea with full freedom for manœuvre. On the contrary, the submarine is favoured when its enemy approaches a hostile shore, where his freedom of manœuvre is hampered by the proximity of the coast and his advantage of speed is thereby partially counterbalanced. Therefore it does not seem desirable that our navy should attempt to establish a defensive cordon of submarines far from our coasts in mid-ocean. For a line held there will be long; its distance from shore will require much time to arrive at and return from station, necessitating excessive numbers of ships. The enemy has no objective in mid-ocean and will not wait there. If he is attacked in that neighbourhood by submarines, he has the advantage of full opportunity to manœuvre freely at high speed. On the other hand, our submarines will gain on every one of the above-mentioned points if they are used for local coast defence and do not go far off shore, say, not more than a day's run. They may well expect to maintain a strip of coastal waters fairly free from the enemy and available for coast navigation, as do the English at the present time. Thus the size and type of coast-defence submarine of about 500 tons now favoured by our Navy Department seems the proper and logical one for American use. It is true that it is a much larger type of submarine which has obtained most Press notice in the current war, but that is because the requirements of the situation were such that the areas best suited to the operations of German submarines were far from German bases. We do not foresee any stragetic reasons that will require our submarines to operate so far from home. American coast defence does not appear to require the largest type of submarines. Nevertheless, the Appropriation Act of this year calls for three of a large size (800 tons), which will prove instructive and useful as experimental boats even if they prove to be larger and more expensive than necessary. There is a great desire on the part of every navy to provide submarines capable of accompanying the fleet and taking part in general actions. For such a purpose a second type of submarine is necessary.

Such a craft will be away from its base for a longer time than coast-defence submarines, and must, therefore, have a larger crew and better quarters. Tactically, also, its requirements must be quite different. As was earlier pointed out in this paper, an automobile torpedo has a greater virtual range when it is fired to meet an approaching target than when it is fired to overtake a retreating target. Consequently an ideal torpedo boat, whether of the surface type or of the submarine type, should have superior speed to that of its probable opponent in order that, however the latter turns, the torpedo boat may assume an advantageous position ahead of the enemy before closing to discharge the torpedo. But this is a difficult condition to satisfy with a fleet submarine. The standard speed of battleships reached 21 knots some years ago, and is now on the rise once more. At present 23 knots may be regarded as the normal speed for foreign battle-ships of the most recent design, and our navy should not lag behind others in this respect. An ideal fleet submarine should have both surface and submerged speeds not less than 25 knots, and a submerged radius of at least two hours at maximum speed. Unfortunately, we cannot get a quart into a pint pot, nor is such an ideal fleet submarine practicable. No submarine even of as large size as 1,200 tons or 1,500 tons, can get sufficiently powerful machinery into her; first, because her hull weight must be great to withstand submergence, and, second, because she must be provided with two heavy systems of motive power, in place of one lighter one, such as surface craft have.

In the present state of engineering we shall therefore be obliged to content ourselves with a surface speed approaching the cruising speed of the fleet under war conditions, or about 20 knots. The submerged speed and radius must be very moderate: sufficient only to serve as a means of passive defence by concealment, but not enough for aggressive manœuvring while submerged. The mechanical limitations thus imposed upon fleet submarines restrict very greatly the tactical freedom of the commander-in-chief who attempts to utilise submarines in a general engagement. Other component elements of the fleet are all capable of acting in mutual support of each other in aggressive attack upon the enemy. The fleet submarine, limited as it is in speed, is incapable of such co-operative attack with other types, for it cannot force itself into the fight. The commander who seriously relies upon his fleet submarines in a general action must place himself upon the strategic defensive and so restrict his freedom of manœuvre as to make it a chief objective to draw the enemy within the pre-established area of the submarines. It is clear that such a limitation is a severe handicap. It is, nevertheless, desirable that our fleet should be accompanied by submarines for use when opportunity serves. Those now building are abreast of present possibilities, but should be improved and developed in succeeding years as engineering progress dictates. The chief distinguishing characteristics for them are high surface speed with adequate surface endurance and habitability. High submerged speed and great submerged radius are comparatively secondary affairs unless most radical improvements are brought about in the methods of submerged propulsion, so that high submerged mobility may be obtained without undue sacrifice of surface mobility.

The conclusion to be drawn from this study is that the Navy Department has made a judicious decision in the combination of military characteristics which it has embodied in its latest designs of submarines for service with the fleet as well as for coast defence.

PROMOTION OF BRITISH TRADE IN FOREIGN COUNTRIES.

THE Federation of British Industries, which comprises a large number of influential associations, firms, and individuals, have had under consideration the circumstances which will affect British foreign trade on the conclusion of peace and the preparations necessary to meet the new situation, and have favoured us with a copy of the recommendations which they have drawn up for the development of the Government service for the promotion of British trade in foreign countries. It appears inevitable that economic conditions after the war, and more particularly those which will exist in belligerent countries, will greatly increase the severity of the competition in foreign markets at the very time that the necessity of meeting the heavy charges consequent upon war expenditure will render it a vital necessity for British productions to secure a greatly increased sale in such markets. This situation will involve a great increase of effort upon the part of all persons, organisations, and individuals concerned with the industry and commerce of the country; but, above all, a very heavy responsibility will be thrown upon the Government Commercial Service, and, in particular, upon the departments and services charged with the promotion of foreign trade and with the collection and distribution of foreign commercial intelligence. The Federation are convinced that these responsibilities will be of such a nature that the duties, character, and scope of these departments and services will require radical re-organisation and a very considerable extension. They fully realise, however, that it is not within the power of any committee to lay down detail reforms, and they have therefore confined themselves to suggesting certain broad principles which in their opinion are essential to any successful re-organisation. The following is a summary of their recommendations:—

That all the activities undertaken by the Government in connection with the promotion of British trade in foreign countries should be concentrated in a single department, and that this department must be the Foreign Office.

That the commercial duties of the Foreign Office and foreign services should include: (*a*) The direction of all services abroad. (*b*) The collection and distribution of all industrial, financial, and commercial information relating to foreign countries. (*c*) The prompt and vigorous support of all British efforts to secure contracts, concessions, or orders. (*d*) Advice to the department in charge of industrial and commercial affairs on all questions in the United Kingdom which may affect foreign trade. (*e*) Advice to His Majesty's Government as to the conditions on which they should permit the issue of foreign loans in the United Kingdom.

That really efficient machinery should be established to co-ordinate the work of the Foreign Office and of the department in charge of industrial and commercial affairs.

That in order to enable the Foreign Office and foreign services to undertake the re-organisation and expansion necessary to the efficient discharge of the functions enumerated above: A large increase should be made in the funds placed at their disposal.

That the re-organisation of the Foreign Office and foreign services should be on the following lines.

Foreign Office.—(i.) The establishment of a large commercial branch, with the provision of extra staff and accommodation on a generous scale. (ii.) This branch to be in the closest possible touch with the industrial and commercial community. (*a*) By frequent personal interviews. (*b*) By personal visits to industrial centres. (*c*) By the appointment of small committees, composed of representatives of the firms most actively interested, to advise the various sections of the commercial branch on matters connected with the countries with which they deal, and to offer suggestions and criticism. (*d*) By the appointment of a central committee, on which prominent members of the industrial and commercial community should form an important element, to perform the same advisory and critical functions for Government departments generally.

The Diplomatic Service.—(i.) Increase of staff to enable sufficient time to be devoted to the study of industrial and commercial questions. (ii.) Insistence that commercial work forms a most important part of the duties of the service, and that a certain period during an officer's service in each grade should be devoted especially to this work as an essential qualification for promotion.

The Commercial Attaché Service.—This should be replaced by the appointment of officers of high rank, to be known as Commercial Counsellors, to each Embassy or Legation, to be in sole charge, under the Minister or Ambassador, of all commercial work in the country. These officers to be given one or more assistants, and rank, emoluments, and position second only to that of the Minister or Ambassador, and to be regarded as regular members of the diplomatic service.

The Consular Service.—(i.) The commercial work of this service to be subject to the direction of the Commercial Counsellors. (ii.) A large increase in the numbers of the regular service. (iii.) A redistribution of posts to correspond with commercial needs. (iv.) Reduction to a minimum of the posts held by unpaid Consuls. (v.) Provision of sufficient clerical and other assistance to enable consular officers to devote the bulk of their time to commercial work. (vi.) Provision of adequate local and travelling allowances.

All Services.—(i.) Only natural born British subjects to be eligible for appointment to any post, paid or unpaid. (ii.) The introduction of a small number of men with practical business experience especially into the commercial branch of the Foreign Office and the Commercial Counsellor service. (iii.) The establishment of a definite and high standard of efficiency which must be reached by all officers at different stages of their career.

This standard to be administered by a Promotion Board with power to postpone the promotion of any officer who does not reach the standard, to demand the resignation of any officer who falls far short of it, and to grant a pension commensurate with past services to any officer whose resignation is demanded.

Training.—Should be based upon a preliminary test of general ability and of a sound general education, to be followed after appointment by a special course in elementary economics, commercial method, and two or more foreign languages. Training should be completed by actual experience of the work of the service, supplemented by frequent opportunities of visiting industrial centres and of acquiring practical knowledge of industrial and commercial questions.

Experts.—A large number of technical and commercial experts should be selected and sent, when required, to investigate and report upon industrial and commercial conditions and opportunities in particular countries and particular markets. Ample funds should be provided to enable the best possible advice to be obtained, and these investigations to be made with sufficient frequency and thoroughness.

EXPERIMENTS ON EARTH PRESSURES.

AT a meeting of the Institution of Civil Engineers, held on December 5th, a paper on the above subject was read by Mr. P. M. Crosthwaite, B.A.I., M.Inst.C.E. The paper commences with a short account of Rankine's theory of earth pressure, and the principles and assumption on which it is founded. Descriptions of former investigations are given in some detail, viz., those of the late Sir George Darwin, and Messrs. Godrich, Wilson, Bell, and Meem. The author concludes that of the experiments made by these investigators to investigate the lateral pressure of earth, those in which model walls were used are of greatest value, but points out that if models are of any size the experimental difficulties are almost insuperable.

The author's experiments, a number of which are described and illustrated in the paper, were made by loading a plunger with known weights and measuring the penetration when the plunger had come to rest after the application of each weight. The materials were enclosed in an open bucket, and their weight was determined. With those data the value of ϕ, the angle of internal friction, can be obtained from Rankine's well-known formula for the safe depth of foundations—

$$d = \frac{P}{W}\left(\frac{1 - \sin.\phi}{1 + \sin.\phi}\right)^2$$

when d denotes the penetration; P the pressure in pounds per

square foot; and W the weight of the material in pounds per cubic foot.

If the formula is true, and the pressures be plotted against the penetrations, the resulting curve is a straight line, and ϕ as calculated from the formula should equal the angle of repose. With sand, garden earth, and cinders and ashes the resulting curves are straight lines, but it was found that the value of ϕ varied with the state of aggregation of the material, *i.e.*, whether it was lightly poured into the bucket, shaken in, or well pounded in. When the material was deposited in the bucket as lightly as possible the angle of internal friction was the same as the angle of repose, but with more consolidation the angle was much greater.

From these materials the author concludes that Rankine's theory holds, provided the proper angle of internal friction is used and not the angle of repose. If, however, this angle is used it would be necessary to introduce a factor of safety into the formula, for a wall designed without one would be theoretically just strong enough and no more. In Rankine's formula there is no factor of safety, and it is concluded that Rankine saw this, and used the angle of repose as covering the worst conditions that need possibly be provided for. The author's experiments show that, for the materials tested, work designed by Rankine's formula, using the angle of repose, would have a factor of safety of $2\frac{1}{2}$ to 4, and he considers that these are not unreasonable figures for such materials.

The experiments on clay give altogether different results, for instead of the penetration varying as the load, it varies as the square of the load, and the penetration curves are parabolas. These results, which were altogether unexpected, are completely confirmed by larger experiments carried out by Messrs. Coode, Matthews, Fitzmaurice, and Wilson, and by Mr. McAlpine in New York. The author is able to give no physical explanation as to why the penetration in clay should vary as the square of the load, but leaves it to the physicists. The law must be capable of some rational explanation, and, if true, it upsets all earth-pressure theories when they are applied to clay; for all accepted theories assume that the angle of internal friction is the same as the angle of repose, and that its value is independent of the pressure. It is suggested that the subject is worthy of further investigation, but that such could hardly be made by a private individual, for the work is tedious, each experiment taking from 24 to 48 hours. Moreover, if the investigation is to be properly carried out, physical and chemical analyses of the clays will be required that could only be made in a well-equipped physical laboratory.

In connection with the earth slides experienced at the Panama Canal, it has been suggested that in clay and shale cuttings there is a critical depth beyond which the sides will not stand, and the author's experiments on clays clearly show that for these this must be the case. Where ϕ is independent of the pressure the depth of the cutting cannot affect the stability of the slope, but where the angle decreases with the pressure it is evident that eventually a depth will be reached beyond which its sides will not stand. This decrease is clearly shown in one experiment on mud for which the angle for a pressure of 0·25 ton per square foot was $17° - 15'$, which decreased to $2°\ 10'$ at a pressure of 1·25 ton per square foot, when it was little better than a liquid.

NEW PATENTS.

Specifications of the following are now published, and we shall be pleased to forward copies post free on receipt of 8d. Address "Mechanical Engineer," 53, New Bailey Street, Manchester.

MECHANICAL, 1915.

Machines for punching structural shapes. Marks. 12139.
Storing of gases under pressure. Acetylene Illuminating Company, and Stephenson. 12205.
Machines for milling screw threads. Berry. 12555.
Metal bending machines. Blake. 15147.
Carburetters for internal-combustion engines. Jennings. 15271.
Valve mechanism of internal-combustion engines. Chorlton and Livens. 16493.
Heating of feed-water for steam generators. Gowans. 16581.
Variable-speed gear. D. Napier & Son, Ltd., and Rowledge. 16595 and 16596.
Appliances for boring metals or other hard substances. Austin. 16684.
Feeding of steam generators. Watson. 16686.
Jet carburetters for internal-combustion engines. Davis. 16755.
Processes and apparatus for converting heavier oils into lighter oils. Lamplough. 16830.
Lubricators for piston rods. Smith, and Smith. 16970.
Carburetters of internal-combustion engines. Newton & Howarth. 17011.
Coil clutches. Carter, and Hans Renold, Ltd. 17134.
Steam-condensing plant. Morison. 17405.
Crucible furnaces. Keith & Keith. 17902.

1916.

Cutting or milling tools. Vickers, Ltd., and Francis, H. 138.
Furnaces heated by oil fuel for melting metals. Ward, J., Townsend, A. P., and Forgham, R. G. 495.
Steam superheaters. Smith, V. 1170.
Multicylinder internal combustion engines. Craig, A. 1515.
Apparatus for cleaning the tubes of steam boilers. Reiter and Gruenwald. 1757.
Capstan lathes. Frisch et Cie, A. 3248.
Boring and drilling tools. Allen, W. G. 3831.
Apparatus for charging articles into furnaces and withdrawing them therefrom. Smith, J. 3909.
Disc valves. Key, T. D. 3970.
Pig-iron breaking machines. Winterbottom, T. 5212.
Furnaces. Yates, H. J., Brayshaw, S. N., and Brayshaw, E. R. 5333.
Method of making lined bearings. Pressed Bearing Company. 6500.
Locking means for nuts and bolts. Willey, S. J. 8984.
Marine turbine installations. Westinghouse Machine Company. 9112.
Pipe joints. Lockley, A. E. 9524.
Liquid fuel furnaces. Richards, C., and Richards, A. 9574.
Water tube boilers fitted with superheaters. Babcock and Wilcox. 9867.
Means for varying the stroke of a reciprocating engine. Wilkinson, H. O. 9878.
Intercepting-valves for compound engines. Davies, H., Mason, P. F., and Wood, A. 10064.
Apparatus for raising and forcing liquids by means of compressed air. Chapman, T. S. 12672.
Lids or covers for crucible furnaces. Keith, J., and Keith, G. 13060.

ELECTRICAL, 1915.

Electrolytic cells. Jenkins, and C. I. (1914) Syndicate, Ltd. 16643.
Electromagnetically actuated contact makers or switches. G. D. Peters & Co., Hibberd, and King. 16765.
Portable electric lamps. Gibson & Benns. 16865.
Carbon-saver for arc lamps. Turner. 17125.
Cooling of electric motors of the enclosed type. Schroeder. 17276.

1916.

Electric welding apparatus. Woltmann, E. 6036.
Electric meters or relays. British Westinghouse Electric and Manufacturing Company. 8310.
Automatic ignition advancing devices for magnetos. Bignon, L., and Rousset, J. C. 13820.

Metal Quotations.—Owing to the irregularity and uncertainty of metal prices in consequence of the war, we are refraining from publishing the usual table of metal quotations until conditions become more normal.

Locomotives for New South Wales.—The Assistant Minister for Railways, Mr. Hoyle, states that the Government has, through the Railway Commissioners, signed a contract with the Clyde Engineering Company, Auburn, near Sydney, for the construction of 300 locomotives, covering a period of five years, beginning April, 1917. He said recently that "The Clyde Engineering Company, being the lowest tenderers, have not only a very large order, but they have agreed to extend their plant, which will enable them to get out 60 engines per year more than one per week. They will begin by increasing their output, and long before the expiration of the term of five years they will be turning out the 60 engines per year. At present the company's output is about one per fortnight. We consider this to be an excellent arrangement, and one of the first substantial efforts to make the Empire self-contained. We are launching a locomotive building industry here which will be the start of one of the largest of its kind in Australia. I have always had a strong desire to build up our industrial greatness, and this is the first result of efforts in that direction.

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Hardness Tests.

THE report which has been published of the Research Committee of the Institution of Mechanical Engineers on Hardness Tests is an admirable example of good work which may be undertaken by the Institution. The Committee was appointed in 1914 and originated in a question addressed to the Engineering Standards Committee as to the best methods of determining the standards of hardness required for shafts or pins revolving at high speeds under heavy loads. In a general way, and to the mind that does not penetrate below the surface of things, the question does not appear to present much difficulty. Such a mind concerns itself only with broad contrasts and not with those minute differences of measurement which it is essential to make when clear definitions have to be formulated. It is easy, for instance, to say at once that cast iron is harder than lead, but judgment is set wondering when the question arises as to which of two samples of lead is the harder, or whether glass is harder than steel, and is still more perplexed when it is faced with the problem of deciding relative degrees of hardness. A variety of methods have been evolved to answer the question. One of the simplest is the scratch test. The fact that a diamond point is capable of scratching almost all other crystals while itself remaining untouched is accepted as proof that it is the hardest of all. In engineering the file test, which is practically a scratch test, was one of the first to be adopted. Subsequently Moh proposed a scale of hardness in which 10 substances were graded such that each would be scratched by the next above, talc being the lowest and regarded as No. 1 in the scale, and the diamond the highest and regarded as No. 10. On this scale a copper coin ranked as No. 3, ductile iron as No. 4·5, and a file as No. 6·5. It is obvious, however, that as applied to metals such a scale was very empirical. Turner's

scratch method was an improvement on this. He used a diamond point which could be loaded by a lever and weight and drawn across a polished surface of the specimen. Pressures on the point of 10, 20, 30, &c., grammes formed the scale, and the pressure which was necessary to produce a decided scratch was taken as the hardness number. It requires little consideration to see that this method is open to objection, involving, as it does, the personal equations of eyesight and sharpness of the diamond point. Following on this several indentation methods have been proposed in turn by Mantell, Foeppl, Unwin, Brinell, and Shore. Foeppl's method consisted in squeezing two cylinders of the material to be tested at right angles, the pressure per unit of flattened surface being taken as the measure of hardness. Unwin employed as indenting tool a small square bar of hardened tool steel, one of the edges of which was forced into a strip of the material 2in. by ½in. by ½in. to be tested, the load P in tons divided by the indentation in inches being taken as the hardness number. Measured in this way he found that the tensile strength, divided by the hardness number, was practically constant. In the Brinell test the indenting tool is a spherical ball, and by an empirical relationship between the pressure, the diameter of the ball, and the diameter and depth of the indentation a scale of hardness numbers is determined. The Shore and the Mantell tests are indentation tests caused by a blow. Mantell used a pyramidal point and a falling weight. In the Shore test, known as the scleroscope, this method has been elaborated, the indentation being formed by the convex point of a hammer weighing 40 grammes, which falls from a fixed height inside a glass tube, and the height of rebound is observed against a graduated scale. It has been found that the arbitrary numbers on the Brinell and Shore scales are related, and that the Brinell number divided by six agrees approximately with the Shore number. It has been generally assumed that hardness measured in one or other of these ways was also a measure of resistance to abrasion and wear, but experience has not borne out this assumption, a striking exception being manganese steel, which, with a low Brinell hardness number, yet gave the best wear number of all steels tested in some abrasion experiments made by Mr. E. H. Saniter, of Rotherham, and described in a paper read before the International Association of Testing Materials in 1912. A consideration of this and other results forms the basis of the enquiry of the Research Committee, and as we purpose giving the report in full, we need not here refer to the precise methods of testing. It was pretty clear, however, at the outset that the ordinary methods hitherto used for testing hardness were not a safe guide in determining the relative resistances of metals to wear, and this conclusion has been confirmed by the Research Committee. Hardness, as Sir Robert Hadfield points out in an appendix to the report, is a vague, indefinite term, and cannot be regarded as a specific property of a material until its characteristics as regards deformation have been clearly defined. Deformation itself causes changes of molecular structure, and hardness measured by indentation methods is really only a measure of compressive stress over a small area, where owing to the deformation caused the stress itself is not uniform, and therefore cannot permit of accurate deductions being drawn. A striking example in this respect is shown by manganese steel, and of course in a greater or less degree other materials. Manganese steel is soft in its undeformed state, but when deformed becomes hard as a result of molecular change. These changes resulting from deformation are impossible to measure by indentation tests, although they largely affect resistance to abrasion, and therefore the suitability of metals in frictional contact under high speeds and heavy loads.

BOOK REVIEWS.

Stresses in Structures. By A. H. Heller, C.E., late Prof. of Structural Engineering, Ohio State University. Revised by Clyde T. Morris, M. Am. Soc. Civil Engineers. New York: Wiley & Sons. London: Chapman & Hall. 9¼in. by 6¼in. 374 pages. Price, 11s. 6d. net.

This volume is entirely devoted to an analysis of the stresses in various forms of roof and bridge trusses, and was designed by its author to act as a book of reference for students, presumably those passing through his hands at the University of Ohio, in their subsequent practical career, as well as for the practical engineer who is too preoccupied to wade deeply into an elaborate treatise when suddenly called on to deal with a new problem. Of books on stresses in built-up structures there is no lack, and the sole claim for originality in the present volume is that methods of treatment are simplified, while at the same time the reader is not called upon to accept many things on faith if he is at all familiar with analytical mechanics and strength of materials. To enable the reader to check his knowledge, most of the chapters are supplemented with a series of questions and answers based on the text. These are well chosen. The work throughout is illustrated with clear diagrams, and the matter selected with a strict regard to the author's aims. Within the limits stated the book is good, and we have pleasure in recommending it.

* * *

Spon's Electrical Pocket-book. A reference book of general electrical information, formulæ, and tables for practical engineers, by Walter H. Molesworth, M.I.E.E., M.I.M.E. London: E. & F. N. Spon. 7in. by 4½in. 488 pages. Price, 6s. net.

Engineers cannot at the present day complain of lack of pocket reference books. Whatever be the particular field in which they are engaged, specialisation seems to increase rather than diminish his need for prompt information on other matters than those in which he is expert, and the wide range that is connected directly and indirectly with electricity is indicated by a glance at the book before us. Where there is such a wide choice of pocket-books no one can claim to rank as best, but we may at least say that this one contains matter in many directions that makes it distinctive, and though the price, as compared with others, appears a bit stiff, it nevertheless deserves a good place in the list. After all, engineering literature in this country is cheaper and better than anywhere else, and, in regard to reference books, the reader can well afford to purchase two or three. We would add, finally, that the book is well printed and well illustrated.

BOOKS RECEIVED.

The Journal of the Textile Institute. Vol. III., No. 3. 16, St. Mary's Parsonage, Manchester.

The Slide Rule. Its operation and digit rules. By A. Lovat Higgins, A.M.Inst.C.E. London: Whittaker & Co. Price 4d.

Wire and Sheet Gauge Tables. A metal calculator for merchants, for office and shop use, in sheet, plate, and rod mills and forges. By Thomas Stobbs. London: E. and F. N. Spon. Price 3/6 net.

Power Transmission by Leather Belts. By Robert Thurston Kent, M.E. New York: Wiley & Sons. London: Chapman & Hall. 110 pages. Price 5/6 net.

"Isherwood" System of Ship Construction.—The number of "Isherwood" vessels contracted for to date in this year is 152, with a total gross tonnage of about 698,875, which is equivalent to about 1,000,000 tons in deadweight carrying capacity, thus making the total number of vessels built, under construction and on order 620, with an aggregate deadweight carrying capacity of over 4,500,000 tons.

DAVEY'S COMPOUND CONDENSING PUMPING ENGINE.

THE pumping engine shown in the accompanying cuts, the invention of Mr. Henry Davey, Conaways, Ewell, Surrey, is of the compound condensing type, and although not provided with steam jackets is designed to give a high efficiency. The engine comprises a high-pressure cylinder, a valve leading from the high-pressure cylinder to the low pressure cylinder, a valve leading from the passage connecting the cylinders to a feed-water heater, and an exhaust valve in the passage to the condenser. Referring to the illustrations, Figs. 1 and 2

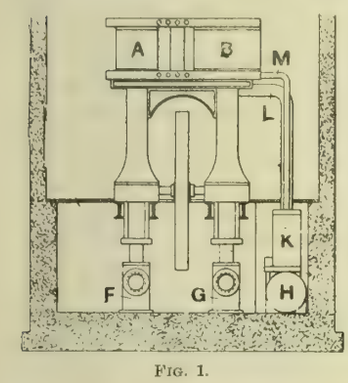


FIG. 1.

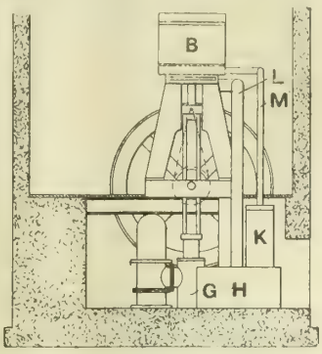


FIG. 2.

DAVEY'S COMPOUND CONDENSING PUMPING ENGINE.

are elevations at planes of right angles of the pumping plant; Fig. 3 is a sectional elevation of the engine cylinders; Fig. 4 is a sectional elevation through the valve passage, feed-water heater, and condenser; and Fig. 5 are diagrams of the steam distribution in the engine.

In the installation illustrated, which represents a compound condensing pumping engine giving 400 b.h.p., the high-pressure cylinder A is of 30in. diam. and 3ft. stroke; for 100lbs. boiler pressure, the low-pressure cylinder B is of 60in. diam. and 3ft. stroke, the number of revolutions being 35 to 40. The cylinders are mounted on standards, and the pistons D, E, are directly connected to the plungers of pumps F, G. The condenser H and feed-water heater K are connected to the engine cylinders through pipes L, M. Both

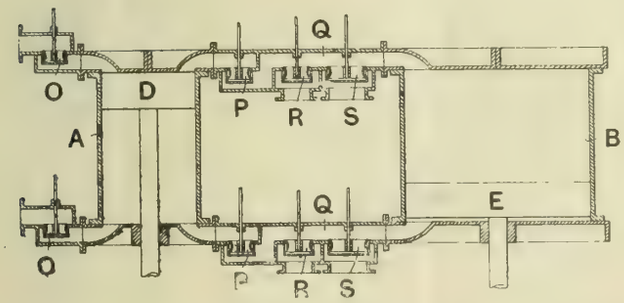


FIG. 3.

DAVEY'S COMPOUND CONDENSING PUMPING ENGINE.

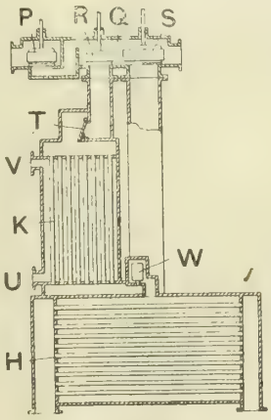


FIG. 4.

cylinders of the engine are double acting, and the high-pressure cylinder is supplied with steam through the valves O. The exhaust from the high-pressure cylinder is controlled by valves P leading to passages Q, through which the steam passes to the low-pressure cylinder. The steam supplied to the feed-water heater is controlled by the valves R, and the exhaust to the condenser is controlled by the valves S. Between the valve R and the feed-water heater there is provided a non-return flap valve T. The feed water is fed into the inlet U and leaves the feed-water heater by the outlet V. A loaded valve W is provided for the escape of air and water from the condenser to the feed-water heater, this valve being mechanically worked from the engine if desired. Since air is heavier than steam, by placing the heater above the condenser the air and water will gravitate to the condenser when the pressure in the heater opens the relief valve or when the valve is opened in any other way. In the arrangement illustrated the valves are of the lift type, but slide valves may be employed on the low pressure cylinder.

Fig. 5 shows a steam diagram of the engine. In this figure the diagram A represents the steam distribution in the high and low pressure cylinders, where the maximum pressure is 120lbs., while B is a similar diagram in which the maximum pressure is 160lbs. C and D show enlarged views of the low-pressure diagram. In Figs. A and C the ratio of the volumes

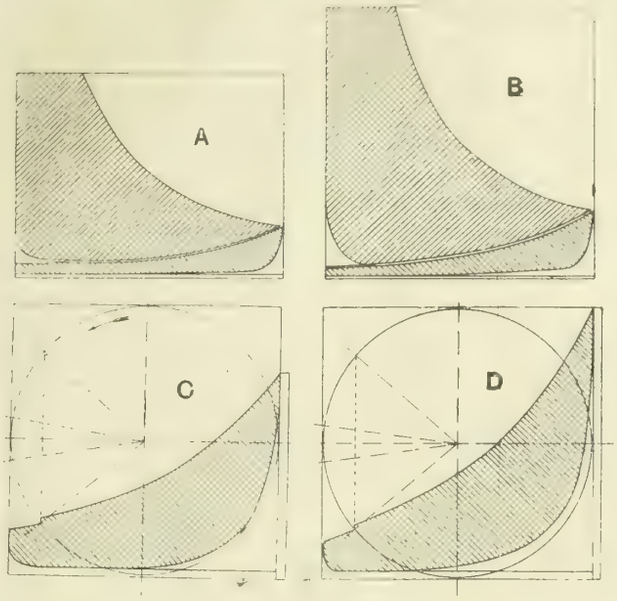


FIG. 5.

of the high-pressure and low-pressure cylinders is 1 to 4, while in Figs. B and D the ratio is 1 to 6.

Instead of heating the feed water by the steam taken from the cylinder at the end of the stroke the valve R leading from the low-pressure cylinder to the feed-water heater is opened shortly before the end of the stroke and before the exhaust valve S is opened. The effect of this is that a diagram with a drop of pressure near the toe is produced as shown in Fig. 5, this drop of pressure being due to the condensation of steam in the feed-water heater. The result of this is that the steam in the feed-water heater is at a higher temperature than in engines as heretofore constructed, a temperature of 180° Fah. being conveniently obtained. At the same time the pressure drop in the low-pressure cylinder caused by the early opening of the valve leading to the feed-water heater is comparatively small, so that there is little loss of power by reason of the opening of the valve.

The two steam cylinders are arranged with pistons connected to cranks opposite each other, and the discharge or outlet valves of the high-pressure cylinder serve as the admission valve to the low-pressure cylinder. It is convenient to arrange the opening of the valve to the feed-water heater when the low-pressure piston has completed about seven-eighths of its stroke. The exhaust valve is opened just before the end of the stroke, and remains open for about one-eighth or more of the exhaust stroke. The exhaust valve then closes and steam in the cylinder at condenser pressure is compressed in the clearance spaces in the passages between the cylinders until it reaches the terminal pressure of the high-pressure cylinder. While the exhaust to the feed-water heater is still open and before the exhaust to the condenser takes place, the water in the heater is heated to nearly the temperature of the steam at a terminal pressure, say at about 180° Fah., the terminal pressure being about 8lbs. absolute. By closing the exhaust valve early in the stroke two thermal effects are produced. Firstly, the isolation of the cylinder from the cooling influence of the condenser for seven-eighths of the stroke, and, secondly, the compression heats the face of the

piston, the cover, and the clearance surfaces to the temperature of the initial steam, thus reducing initial condensation and avoiding a pressure drop between the two cylinders. By supplying superheated steam to the high-pressure cylinder by isolating the low-pressure cylinder from the condenser and by compressing the condenser steam, losses of heat are avoided and steam jackets may be dispensed with. Means are provided for maintaining a constant compression in the low-pressure cylinder for varying degrees of vacuum in the condenser, and at starting the engine compression is altogether removed by a suitable automatic governor. It will be seen that the higher the terminal pressure the greater will be the percentage of heat recovered in the feed-water heater.

LIQUID MEASURING PUMPS.*

BY F. J. SCHLINK.

THE importance of the measuring pump is principally due to the large quantities of gasoline sold as fuel for motor cars, by far the greater part of this commodity being sold through the various forms of measuring pumps. The principal advantages of this type of apparatus lie in its convenience in delivering gasoline directly to the tank of the automobile, with a minimum of evaporation, spillage, and fire hazard.

The first and most common type of measuring pump is the piston pump, which is in principle the usual plunger pump with stops which act to define accurately the limits of the piston stroke, and consequently the volume generated by the piston on each cycle. Both single-acting and double-acting piston pumps are used for measuring purposes. In addition to the pumps with reciprocating pistons, pumps with rotating pistons are used, the application of these at the present time being more familiar in the so-called molasses pumps, which are especially adapted to the handling of viscous liquids. Most reciprocating and rotary piston pumps are provided with a counter or tally to indicate the number of strokes or cycles which have been completed. Such counters should be so designed and located that they will operate correctly, indicate unmistakably, be actuated only very near the conclusion of the stroke or cycle, and be plainly visible to and readable by both merchant and customer.

In a second type of apparatus, the measurement is performed by passing the liquid through a meter, commonly of the nutating-piston type, the discharge of liquid through the meter being produced either by displacement of the oil over water, by pneumatic pressure, or by mechanical pumping. With the type of meter now used, it is important that the rate of flow through the meter be maintained as nearly constant as possible, and the liquid stream must be kept free from solid particles and sediment, or the meter regularly and carefully cleaned.

A third type of measuring system is founded upon the principle of overfilling a measuring chamber, supplying liquid until an excess is present over the nominal delivery, and then removing the excess by abstraction to a definite level. The liquid may be supplied to the measuring chamber by air pressure, by evacuating the chamber with a vacuum pump, or by direct mechanical pumping from the supply tank. The abstraction of the excess may be performed either by gravity through an overflow pipe, or by siphoning, the height of the liquid remaining being determined by the vertical height of the face of the orifice of such pipes above the bottom of the measuring chamber. In a modification of this type, the measurement is obtained by direct reading of the height of the liquid column on a graduated scale, at the beginning and end of the withdrawal of the liquid from a tank or cylinder. The cross-sectional area of such tanks must be limited in order that the volume value of the scale interval be not excessive.

A portable apparatus is also in use, comprising a small storage tank and a measuring pump, the whole arrangement being adapted for moving to the place of filling most convenient to the purchaser. Such devices favour a higher precision than most stationary tanks in that the suction lift can be kept at a minimum, and the danger of vaporisation and leakage below the piston is much reduced.

In the testing and inspection of measuring pumps it is essential to determine whether the installation is free from inward leaks of air and outward leaks of gasoline. Leaks of either kind are fatal to accurate measurement, and any adjustment made before the correction of defects of this kind cannot be expected to be permanently effective. Much trouble of this nature can be prevented by following with scrupulous exactness the instructions of the manufacturers, which are provided to guide the owner in making the installation.

The principal causes of short delivery of pumps of the piston type are leaking of foot valves, and formation of vapour or air space under the piston, resulting from excessive virtual suction lift or leaky piping, or piping containing traps tending toward the periodical retention of vapour. It appears that a total vertical suction lift greater than 7ft. may be excessive with the ordinary commercial (not "blended" or "casing-head") gasolines. "Casing-head" or "blended" gasoline should not be lifted any appreciable vertical distance on the suction side in those types of pumps in which the piston and cylinder form the measuring element, on account of the vaporisation difficulty already mentioned. Special installations, in which the pump is located at or near the level of the supply tank, should be employed for the last-mentioned grades of gasoline. Another source of error which should be guarded against in design and installation of piston measuring pumps is the inertia of the moving liquid column.

The use of long filling hoses, and of hoses so arranged that they cannot be readily drained, results in cases of short delivery to individual purchasers; this should be obviated by so relating the length of hose and the height of hose connections that the hose can always be readily drained to a definite level. A measuring pump should not be installed inside a building with the hose connection outside, unless so arranged that the manner of operation of the pump is clearly visible to the purchaser. The writer also questions the advisability of permitting the use of a shut-off cock on the outer or delivery end of the hose, as its use may readily operate to prevent the regular drainage of the hose into the customers' tanks.

It is recommended that the design of piston type measuring pumps should tend toward types which cannot be operated through less than full strokes without that incompleteness of the cycle being clearly indicated to the customer. This certainty of stroke completion is readily obtainable in simple designs, which so far as the writer knows have not yet been offered for use. In order to prevent the short deliveries consequent upon operating the piston pumps at less than full stroke, they might well carry a clearly legible placard or notice, reading "This Pump to Deliver—Gal. for Each *Full* Stroke."

Pumps which provide for the return of undelivered liquid to the storage tank should be equipped with some manner of device which will prevent this return taking place at the same time that liquid is being delivered to the purchaser, as such diversion of a portion of the customer's purchase constitutes an easy means to fraud.

In testing pumps, the hose should be removed if this is feasible, and the test delivery made from the pipe outlet, unless a suitable can-filling outlet is provided. Test should be made with a standard measure of suitable capacity and of the conical type, used in combination with a cylindrical graduate reading to cubic inches, or by a measure of special form, similar to that designed by Mr. Theo. Seraphin, which comprises a zero graduation for the correct discharge, and additional graduations for deliveries in excess and efficiency, so arranged as to cover the normal range found in the field work. Two speeds at least, one faster and one slower than normal operation, should be used in the test in order to determine whether or not the action of the pump is substantially independent of the speed of operation.

It is recommended that piston measuring pumps which have been standing unused for a considerable length of time be operated for one or two strokes to eliminate the first stroke short delivery which often occurs on account of valve leakage, vaporisation, thermal contraction, &c.

Results of the tests in the field indicate that pumps in service show a decided tendency towards under-measurement, this being due to the fact that nearly all of the defects of construction or installation tend to produce errors in this one direction. These include: leaks of air and liquid, retention of liquid by the hose, vapour formation consequent upon excessive suction head, failure to complete the full stroke, and slippage of liquid past valves and piston.

* From Technologic Paper No. 81 of the United States Bureau of Standards.

REPORT OF THE HARDNESS TESTS RESEARCH COMMITTEE.*

THE Committee was appointed in 1914 "to report on a Hardness Test for Hardened Journals and Pins," and its membership now stands as follows: W. Cawthorne Unwin, LL.D., F.R.S. (Chairman); Archibald Barr, LL.D., D.Sc.; Sir Robert A. Hadfield, D.Sc., D.Met., F.R.S.; Captain H. Riall Sankey, C.B., R.E., ret.; T. E. Stanton, D.Sc., F.R.S.; and A. E. H. Tutton, D.Sc., F.R.S.

The Committee originated in some letters from the Mirrlees Watson Company to the late Mr. Leslie Robertson, the secretary of the Engineering Standards Committee, who suggested that the question was one suitable for investigation by a Research Committee of the Institution. The Mirrlees Watson Company wrote that "they had found difficulty in fixing a standard of hardness—for instance, in bearings where shafts or pins work at high speeds under heavy loads."

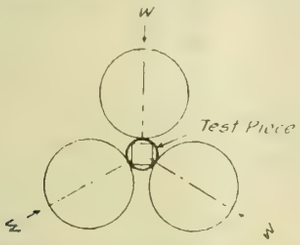


FIG. 1.—METHOD OF WEAR TEST BY ROLLING ABRASION.

The Committee has held several meetings, and has corresponded with some manufacturers and others who were likely to have adopted some method of testing hardness. A memorandum was prepared by the chairman, Appendix I., on such methods of testing hardness as were known to have been used. It appeared that for ductile materials an indentation test (Brinell or Shore scleroscope) was largely used, and was found to give useful information. Both these methods appeared less satisfactory for very hard materials, such as those indicated in the reference to the Committee. Further, it had been shown by Mr. Saniter that resistance to wear, as in the case of a pin or journal, did not directly depend on the hardness as measured by the indentation test.

The question of the property of materials which ensures resistance to wear on rolling or sliding surfaces appeared to be strictly within the reference to the Committee. It was therefore decided that experiments on resistance to wear, and especially in the case of dry surfaces, should be made at the National Physical Laboratory. Dr. Stanton designed more than one form of testing machine for this purpose, and carried out the researches of which an account is given in the paper which forms part of this report. Brinell and scleroscope tests were made at the same time, so that a comparison could be made between the resistance to wear and the ordinary indentation measure of hardness. The form of testing machine designed by Dr. Stanton, in which there is a definite sliding between dry revolving surfaces, seems likely to be of considerable value in solving the precise question put forward by the Mirrlees Watson Company.

The Committee is much indebted to Sir Robert Hadfield for supplying the materials on which Dr. Stanton's tests were made; also to Mr. R. G. Batson, of the National Physical Laboratory, to whose care in making the tests the success of the research was due. The Research Council of the Board of Education have made a grant of £100 supplementing that from the Institution.

REPORT ON EXPERIMENTS MADE AT THE NATIONAL PHYSICAL LABORATORY BY DR. T. E. STANTON AND MR. R. G. BATSON.

A description of the nature of some of the better known of the various tests which have been devised for obtaining the relative resistance of materials to surface deformation, to all of which the term "hardness tests" is sometimes loosely applied, is given in Appendix I. by the Chairman of the Committee. A preliminary examination of these methods shows that each of them falls into one or the other of two distinct categories. These are: (1) Abrasion or scratch tests, in which particles of the material whose "hardness" is to be determined are torn away from its surface by sliding contact with some other substance, whose corresponding resistance is so high that its surface remains unimpaired by the action. (2) Indentation tests, in which the surface of the material under test is permanently distorted by the pressure of a hard steel ball, cone, or knife edge.

If each of these methods were a measure of the same definite property of the material which is as characteristic of it as, say, its elasticity, it is evident that the ratio of the results of any two of the methods would be the same for every material tested. Comparisons between the results of these various tests have formed the subject of several researches which have been published during recent years. The general conclusions, as summarised by Prof. Turner in his paper on "Hardness," read at the Iron and Steel Institute meeting of 1909, appear to be that, although an approximate agreement may seem to exist between the various methods when applied to the case of relatively pure metals in their cast or normal state, yet when the resistance to deformation is due to tempering or to mechanical treatment no comparison is possible.

That this should be so would seem to follow from the consideration that the resistance which any so-called hardness test is supposed to measure is that which the body under test exerts against a complex distribution of stress over its surface which has partially deformed or disintegrated it, and it is evident that its value will depend, not on the stress constants of the material such as its yield-point, ultimate tensile and shear stresses, but on intermediate stresses, the precise nature and distribution of which are unknown and whose ratio to the stress constants may not be constant for the same method. If, therefore, such resistance, without qualification, be defined as the hardness of the material in its broadest sense, it is clear that, as pointed out in the memorandum to the Committee communicated from the members of Sir Robert Hadfield's laboratory (Appendix II.), hardness is no more a definite quality of a material than is the strength of a piece of steel of definite dimensions. In the latter case, if the nature, amount, and distribution of the stress are known, its resistance has a definite value which can be calculated. The only difference between this case and that of the hardness test is that, since in the determination of hardness there is no possibility of estimating the stress magnitude and distribution, we are driven more to direct observation of the consequences of such distribution than to a calculation of these consequences from the known characteristics of the material. Mechanical phenomena of this kind are familiar to engineers under other aspects, such as in the cases of the resistance of ships and aircraft to propulsion; but whereas in these latter cases the problem is to determine the resultant force exerted by the unknown pressure distribution, in the present case, as in the corresponding one of the resistance of materials to impact, the unknown quantity is the ultimate resistance of the material to the unknown stress distribution. In all the cases, however, the practical method of solution is an experimental one, and consists of setting up a similar, or nearly similar, state of stress on a specimen of the material whose behaviour is under investigation and noting its effects.

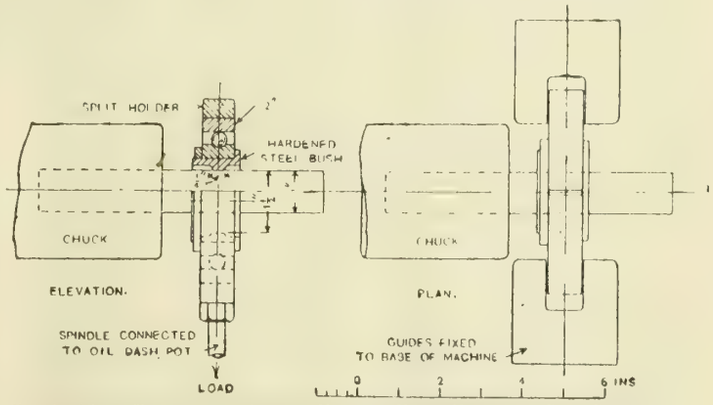


FIG. 2.—WEAR TEST BY THE SANITER METHOD (USING HOFFMANN BALL BEARING).

It cannot, however, be said that modern engineering practice is entirely in accordance with the views laid down above, although the development of what are called "wear" tests in

* Presented at a meeting of the Institution of Mechanical Engineers, November 17th, 1916.

recent years is an indication that it is coming to be recognised that the results obtained in the relatively simple cases of stress distribution in the indentation test or the scratch test are not applicable to those in which the action is a combination of the two effects of normal pressure and sliding. For example, there are wear tests for measuring the particular form of disintegration which takes place on the surface of steel rails due to the rolling abrasion of heavily loaded wheels. The characteristics of this kind of wear are the extremely small amount

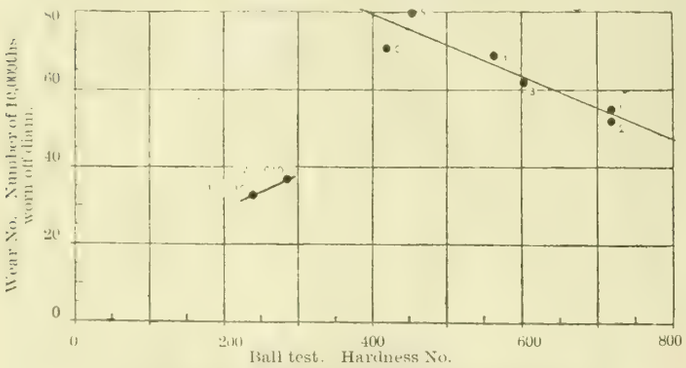


FIG. 3.—WEAR TEST ON SIR ROBERT HADFIELD'S SPECIMENS BY THE SANITER METHODS.

of the relative movement between rail and wheel and the high intensity of the compressive stress at the line of contact. On the other hand, there are wear tests of lubricated surfaces in which the pressure is relatively small and the rate of slipping large.

Notwithstanding this development, there seems to be no doubt that with many engineers it is still customary to regard the hardness as determined by an indentation test as a definite property of material, and as a measure of the resistance of the material to wear of any possible kind that is likely to be experienced in its use. In the face of this practice it appears to be of importance to determine under what circumstances the custom here referred to may be flagrantly misleading, or merely a rough guide which is better than no guide at all. As pointed out in Sir Robert Hadfield's memorandum, the use of an indentation test in the case of manganese steel rails is highly misleading; but, on the other hand, in Mr. Saniter's wear tests of ordinary carbon steels the correspondence between the results of the indentation and wear tests was fairly close.

On looking into the available evidence it appeared that the ground hitherto covered was not sufficient to enable any broad generalisation to be attempted, and the Committee therefore decided, as a preliminary research, that a comparison should be made of the results of both hardness tests and wear tests of materials whose composition and thermal and mechanical conditions of production extended over a wide range. A series of experiments for this purpose were accordingly undertaken at the National Physical Laboratory.

On consideration of the method of wear test to be adopted, the use of the machine previously constructed in the laboratory for wear tests under rolling abrasion suggested itself. In this machine the specimen is in the form of a disc 1in. diam. and about ¼in. thick, which is placed between three hardened steel rollers as indicated in the sketch, Fig. 1, each roller being capable of independent rotation in a practically frictionless bearing. The upper roller is loaded with a weight W, and its axis is also free to move in the vertical direction, so that when it is rotated motion is communicated to the lower ones by the rolling friction of the ring. By making the ring solid and the load considerable, the machine is used for wear tests under rolling abrasion, or by making the ring hollow and using comparatively small values of W the test becomes a fatigue test under alternating bending stresses.* Several preliminary sets of tests were made in this machine, and the results were considered fairly satisfactory; but it was felt that the machine could not be recommended for general workshop use owing to the complication of working parts and the extreme care needed to prevent slipping of the steel rollers as the test proceeded and the specimen became worn. It was decided, therefore, to make use of some simpler form of rolling abrasion test, and as a Wöhler fatigue-testing machine was available which with slight alterations could be adapted for wear tests by the method used by Mr. Saniter,* the necessary modifications were put in hand.

In this method the specimen is fixed in a chuck revolving at a high speed and carries a hardened steel ring (of internal diameter about twice that of the specimen), to which is attached a dead load, and wear takes place due to the rolling of the steel ring on the surface of the specimen, Fig. 2. In Mr. Saniter's machine the diameter of the specimen was ½in., the internal diameter of the wearing ring was 1in., the speed was 4,000 revs. per minute, and the load 205lbs. In the fatigue-testing machine adapted for the present tests, the speed was 2,200 revs. per minute, the diameter of the specimen was 1in., and that of the ring 1½in. The load was 410lbs. The wear was taken as the reduction in diameter in ten-thousandths of an inch after 200,000 revs. of the specimen. As it was considered desirable to have a quantity to represent the resistance to wear, this was taken to be the reciprocal of the above values multiplied by 1,000.

The materials used for the tests consisted of six differently heat-treated specimens of nickel-chromium steel containing

TABLE I.

Marks.		Hardening.	Tempering.		Brinell Hardness No.		Scleroscope No.			
One end.	Other end.	Temp.	Temp.	How Tempered.	Unworn Surface.	Worn Surface.	Unworn Surface.	Worn Surface.	Wear.	Resistance to Wear
8986-1	1	850°C. Oil	None	—	720	—	98	108	55	18
,,	2	,,	200° C. Air	Oil Bath	720	-	98	113	52	19
,,	3	,,	300° C. ,,	,,	605	605	90	101	62	16
,,	4	,,	400 C. ,,	Melt.	565	565	86	90	69	14 5
,,	5	,,	500° C. ,,	Gas Muffle	453	455	77	80	80	12·5
,,	6	,,	600° C. ,,	,,	420	420	67	71	71	14
1 M	(Manganese Steel)		950 C. Water	—	219	230	34	71	33	30
2 M	(Manganese Steel)		as forged	-	277	284	44	78	37	27

0·7 per cent. carbon and two samples of manganese steel, kindly supplied by Sir Robert Hadfield. On analysis the composition of these steels was found to be:—

	C.	Si.	Mn.	Cr.	Ni.
Hardened Steel... ...	0·7	—	—	2·0	2·5
Manganese Steel ...	1·36	0·36	13·10	—	—

The results of the rolling abrasion tests on these specimens are given in Table I., in which are also tabulated the particulars of the heat treatment, supplied by Sir Robert Hadfield, together with Brinell hardness tests and scleroscope tests of the surfaces before and after wear, made at the National Physical Laboratory.

For convenience of comparison the results of the rolling abrasion tests and the ball hardness tests on the original surfaces are also plotted in Fig. 3, in which the ordinates are the values of the wear as defined above and the abscissæ the corre-

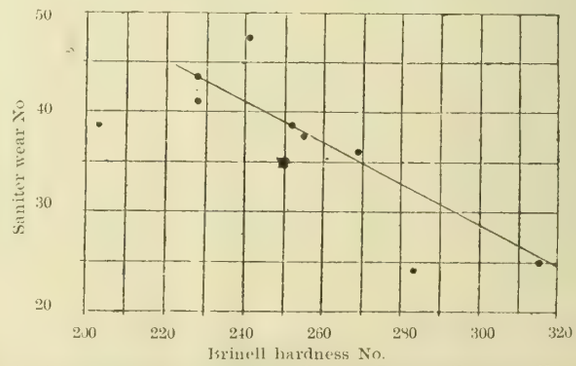


FIG. 4. COMPARISON OF SANITER WEAR NO. AND BRINELL HARDNESS NO. ON A 0·7 PER CENT. CARBON STEEL (Heat treated).

sponding values of the ball hardness test, determined in the following manner: The ball, 10 mm. diam., and the specimen under test were placed between the compression-plates of a Wickstead testing machine, and the load run on to 3,000 kilos. (W), and allowed to remain at this value for 30 seconds. The diameter of the indentation was then measured in a micro-

* Journal Iron and Steel Institute, 1908, No. 1, pp. 54-70.

* Journal Iron and Steel Institute, 1908, No. 3, pp. 73-80.

meter microscope, and the area of the indentation was calculated from the formula:

$$A = 2\pi (R^2 - \sqrt{R^4 - r^2 R^2}),$$

where R = radius of ball in millimetres and r = mean radius of indentation in millimetres. The hardness number was then taken as the value of $\frac{W}{A}$.

From inspection of Fig. 3 it will be seen that the plotted points for the hardened steels lie fairly well about the straight line shown, and the results may be taken as an indication that for the same material the resistance to rolling abrasion is roughly proportional to the ball hardness number. This is in agreement with Mr. Saniter's experience with the same method of test as shown in Fig. 4, in which his results for a 0·7 per cent. carbon steel heat treated in various ways are plotted. The comparison, however, is not a safe one, as cases frequently occur in which a considerable departure is found from this approximate relation. The extremely high value of the ratio of the rolling abrasion resistance to ball hardness number in the case of the manganese steels confirms existing knowledge of the properties of these steels, and is also in agreement with the results of Mr. Saniter's tests. As illustrating the important fact brought out by Sir Robert Hadfield's memorandum that the resistance to rolling abrasion of manganese steels is the resistance to deformation of already deformed manganese steel, which is known to be high, it will be seen from the values of the scleroscope hardness after rolling, given in Table I., that in the case of the manganese steels this was practically doubled by the rolling, whereas that of the hardened steels was only increased by amounts ranging from 4 to 15 per cent. It is of interest to note from the figures that, even when this increase of hardness is allowed for, the resistance to rolling abrasion of the manganese steels is still considerably higher than would have been predicted from the ball hardness tests.

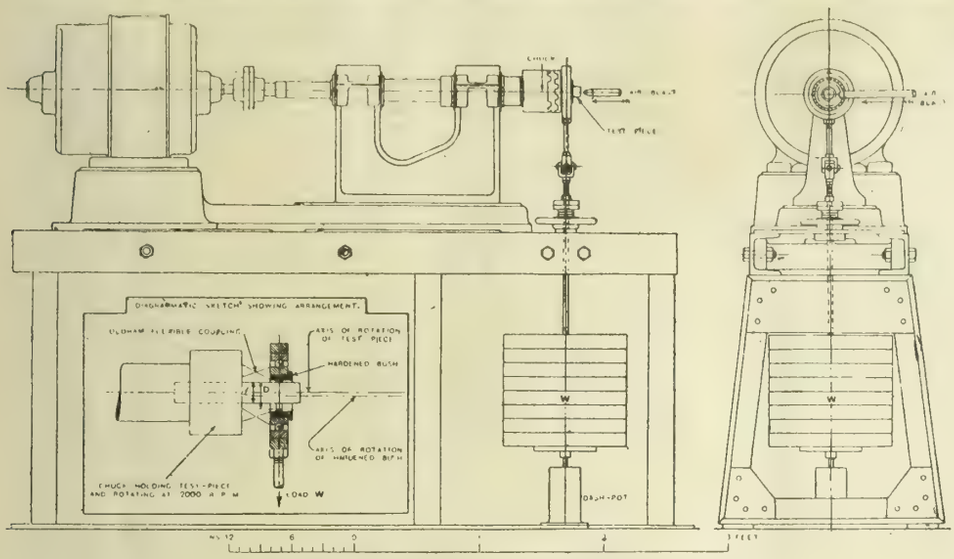


FIG. 5.—ARRANGEMENT OF SLIDING ABRASION TESTING MACHINE.

As regards the nature of the test, it may be assumed that, on first putting on the load, the yield-point of the material of the specimen on an extremely narrow strip of the surface of contact is exceeded, and that slight deformation takes place depending on the radius of the wear ring and the amount of the load. After a few revolutions, therefore, there will be a thin ring of material round the specimen which has been permanently strained, and whose resistance to deformation is greater than that of the original material. Wear will then begin to take place by the gradual disintegration of this ring under the repeated loadings, and also under the extremely small but definite elastic slipping of the surfaces over each other, which is the well-known characteristic of rolling.

Another characteristic of the test is that part of the material worn away during the progress of the test appeared to be rolled into the surface again, and finally came away in flakes. In the description of Mr. Saniter's machine* it is stated that the speed of the machine is such that the abraded particles are removed by an induced current of air. This effect may be an advantage or otherwise, according to the similarity obtained to the conditions of practice. If the comparison required is the relative wear of steel rails, it would appear that the re-rolling action is a more exact copy of practical conditions of use than when it is prevented. It will be clear, however, that in this test what is actually measured is the resistance to disintegration of already deformed material, and that, as pointed out by Sir Robert Hadfield's memorandum (Appendix II.), this resistance will depend on the amount of the deformation produced, and has little relation to the material in its unstrained condition. As regards the value of the method, it was considered that as a means of predicting the relative resistance to wear under conditions of rolling abrasion under heavy loads, *i.e.*, such as the wear of steel rails, the test was a comparatively easy and rapid method of obtaining the information desired, if the following precautions were observed: (1) The fixing of the specimen so that its axis is accurately in line with the axis of rotation of the chuck, (2) Frequent renewal of the wearing ring, and calibration of each new ring on a specimen of standard material.

The reason for these precautions is that any slight vibration of the specimen increases the rate of wear, and this vibration may be set up by want of alignment of the specimen or by unequal wear of the wearing ring.

From the foregoing discussion of the characteristics of the rolling abrasion test, there appeared to be some probability that although its results were applicable to cases of wear due to high pressure and very small relative motion, they might not be applicable to cases of the wear of surfaces in which the pressure is relatively small and the amount of relative movement is large. This appears from the consideration that in the latter case no permanent deformation corresponding to the yield-point is reached over the surface exposed to wear, but that by the relative sliding small particles are bodily detached without permanently distorting the surrounding particles. This is the case of the wear of workshop gauges, hardened steel pins and collars, &c. It was decided, therefore, as the next step to attempt to devise some form of wear test which would apply to cases in which the relative movement of the surfaces was considerable. A system of toothed gearing connecting the abrading ring and the specimen first suggested itself, but on going into the design the mechanical arrangements were so complicated and costly that the machine was not put in hand. Finally, the idea occurred of connecting the abrading ring (internal diameter D) to the chuck by means of an Oldham coupling, so that both ring and specimen (diameter d) should complete a revolution in the same time, the line of contact

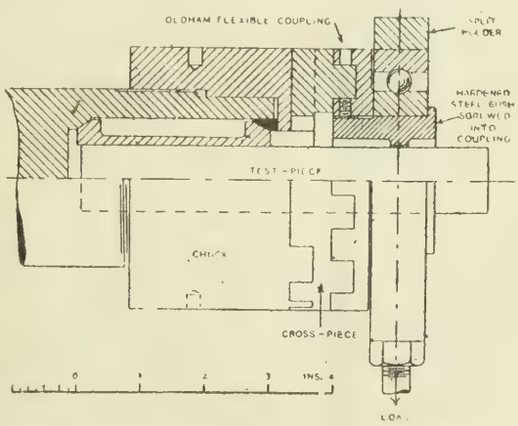


FIG. 6.—DETAIL SHOWING SPECIMEN, APPLICATION OF LOAD, FLEXIBLE COUPLING, AND CHUCK.

* Journal Iron and Steel Institute, 1908. No. 3, page 75.

remaining fixed relative to the machine. In this way πD inches of the surface of the ring and πd inches of the surface of the specimen passed the line of contact per revolution, the slip of the ring over the specimen would be $\pi\ (D - d)$ inches per revolution. The chief practical difficulty of the device appeared to be the difficulty of lubricating the sliding surface of the Oldham coupling so that it would run satisfactorily at 2,200 revs. per minute, and it was evident that if the amount of sliding was large, that is, D considerably greater than d, there was a strong probability that seizing would occur. The chances of successful working appeared sufficient, therefore, to justify a trial of the method, and a design was got out. The details of the machine are shown in Figs. 5 and 6. The cross-piece of the coupling was made of brass with four slots on each side to make the wearing surface fairly large. On the completion of the machine some preliminary tests were made with different rates of slip, and it was found that with a load of 410lbs. the sliding surface of the coupling worked satisfactorily up to a slip of a quarter of an inch per revolution of the specimen, but that beyond this value there was a tendency to seize. The tests were accordingly carried out at this value of the slip. The results were quite satisfactory, but it was evident that if the tests were to be comparable with the wear of tools, gauges, pins, &c., it would be necessary to prevent the action referred to when discussing the previous tests, by which some of the abraded particles were continually re-rolled into the surface. This was accordingly done by directing a strong air blast from a compressor on to the surface of the specimen during the whole of the test. By this means the abraded particles were removed, and any rise of temperature in the specimen was prevented.

The results of the tests by this method, which may be called a sliding abrasion test, were, in one important particular, in marked contrast to those obtained by the rolling abrasion method, in that they indicated a possibility of making a wear test without gradually impairing the condition of the worn surfaces. For example, taking an extreme case, even when the loads on the wearing rings were the same in the two methods, there was very little evidence in the sliding abrasion test of that gradual hardening of the surface as the test proceeded which was so characteristic of some materials under the rolling abrasion test. This was shown by making tests with the scleroscope on the surfaces before and after abrasion.

As might have been anticipated, an important condition affecting the rate of wear was the freedom of the surfaces from the slightest trace of lubricant. In the early stages of the work it was found that occasionally a little oil was carried over from the air compressor by the compressed air, with the result that the test was a complete failure, and it was not until special precautions had been taken to keep the surfaces dry that consistent results were obtained. Under these conditions, however, repetitions of the tests on the same specimen were in very good agreement.

It was considered, therefore, that for the object of the present investigation, *i.e.*, the comparison of the results of the ordinary ball hardness tests with those of a wear test of a satisfactory character, the machine here described would be quite suitable, and a series of tests on a wide range of materials was carried out. A large number of these materials

TABLE II.

Test No.	Marks.	Condition of Material	Analysis							1 Brinell Test.	2	3 Scleroscope Test.	4	5 Sliding Abrasion Test	6	7	8
			C.	Si	Mn.	S	P	Cr.	Ni.	Unworn surface.	Worn surface.	Unworn surface.	Worn surface.	Thickness removed mils. per 1,000 ft. slip.	Resistance to sliding abrasion.	Ratio. Brinell Number / Scl. No.	Ratio. Brinell No./Resistance to sliding abrasion.
1	6	Hardened in oil at 850 deg. C.; tempered in gas muffle at 600 deg. C.	0.70	—	—	—	—	2.0	2.5	420	420	67	68	0.7	140	6.3	3.0
2	1010 2	Manganese steel as forged	1 36	0.36	13.10	—	—	—	—	277	284	44	46	2.2	45	6.3	6.2
3	1010 1	Do quenched at 950 deg C in water	1 36	0.36	13.10	—	—	—	—	219	230	34	39	2.1	48	6.4	4.6
4	1968A	Do water-toughened	1 26	0.11	9.22	—	—	—	—	203	—	30	31	2.0	50	6.8	4.1
5	1010	Do do.	1.18	0 14	12.29	—	—	—	—	206	—	30	32	2.1	48	6.9	4.3
6	2055	Do do	1 48	0 25	15.23	—	—	—	—	228	—	34	37	1 9	53	6.7	4.3
7	A	Carbon steel as rolled	0.52	0 10	1.26	0.05	0.09	—	—	234	237	41	41	1.3	77	5.7	3.0
8	8	Do. do.	0 50	0 19	0 94	0.07	0.07	—	—	228	228	36	35	3.9	26	6.3	8.8
9	11	Do do	0 60	0 15	0.93	0.04	0.10	—	—	252	248	40	39	0.9	110	6.3	2.3
10	3123C	Do. do.	0 75	0.20	0.84	0.04	0.05	—	—	273	282	50	50	0.8	125	5.5	2.2
11	2217	Do oil-toughened	1 62	0.15	0.29	0.02	0 02	—	—	346	349	62	61	0.5	200	5.6	1.7
12	1772A	Do do.	0 43	0 14	1.44	0 06	0.06	—	—	216	—	37	37	2.9	35	5.8	6.2
13	6B	Do do	0 44	0.48	1.01	0.06	0.06	—	—	222	—	37	38	3.2	31	6.0	7.2
14	2250 958	Do as rolled	0 65	0 13	0.60	0.02	0.03	—	—	235	—	41	42	1.1	91	5.7	2.6
15	2250 955	Do, toughened	0 65	0.13	0.60	0.02	0 03	—	—	337	—	61	61	0.3	330	5.5	1.0
16	2250 956	Do do.	0.65	0.13	0.60	0.02	0.03	—	—	830	—	58	58	0.2	500	5.7	0.7
17	720 1	Do mild steel	0.21	0.02	0.46	0 05	0.06	—	—	115	116	21	24	5.3	19	5.5	6.0
18	704/1	Do mild steel mechanically hardened to 35 tons per square inch	0 04	0 05	0 41	0.04	0.07	—	—	149	144	37	37	5.5	18	4.0	8.3
19	A1629	Rail steel, as rolled	0 45	0 11	0 97	0.05	0 05	—	—	190	—	34	36	2.65	38	5.6	5.0
20	B1631	Do do	0.52	0 15	0.75	0.01	0.03	—	—	206	—	37	38	1.27	80	5.6	2.6
21	1908D	Self-hardening steel, air hardened	0.60	—	—	—	—	3 5	W 16.2	627	—	103	103	0.2	500	6.1	1.3
22	1109D	Special steel, water-toughened	0 60	0.62	5 0	0.05	0 06	—	Ni. 15 0	175	—	26	29	1.6	63	6.7	2.8
23	3137D	Do. oil-toughened	0.66	0.15	0 23	0.02	0.03	2.5	2.8	364	—	60	61	2.8	36	6.1	10.1
24	1795E	Do. annealed	0.35	0.08	0.66	0.05	0.03	1.75	3 7	255	-	45	46	9.6 & 26.6	10 to 4	5.7	25 to 64
25	2297	Do	0.57	0 20	0.76	0.05	0.06	1	—	271		47	47	0.5	200	5.8	1.4
26	3109	Do.	0.33	0.07	1.21	0.05	0.06	1 25	—	296		41	41	1.5	67	5.5	3.4
27	1795G	Do	0.20	0.04	0.38	0.05	0.05	2	4	366	—	61	63	2.0 & 4.6	50 to 22	6.0	7.3 to 16.6
28	3121	Do	0.31	0.05	1.18	0.05	0.08	1	3	332	-	55	56	4.2	24	6.0	13.8
29	3102	Do.	0.18	0.03	0.48	0.03	0.03	0.5	2 5	165	—	28	29	2.8	36	5.9	4.6
30	68	Gauge steel, hardened	1.02	0 31	0.45	0.02*	0.03	1.43	0.03	720–740*	—	107	106	0.35	290	6.8	2.5
31	4789	Do. do.	0.86	0.18	1.34	0.02	0.03	0.05	—	675–695*	—	100	101	9 1	1.000	6.8	0.7
32	B D	Do. do.	0.97	0 12	0.26	0.01	0.02	0.14	W1 38 V 0.34	725–750*	—	108	112	0.4	250	6.8	3.0
33	C.	Do. case hardened	0.28	0.05	0.91	0.08	0.06	0.04	—	—	—	110	111	0.2	500	—	—
34	F	Do. unhardened	0 72	0.12	0.22	0.01	0.07	4 16	W–12.69 V – 0.34	228	—	37	40	14.7	7	6.2	32.6
35	719	Admiralty bronze								75	82	17	26	4.9	20	4.4	3.8
36	708	Phosphor bronze								131	137	26	29	1.0	100	5.0	1.3

* Values approximate owing to flattening of ball.

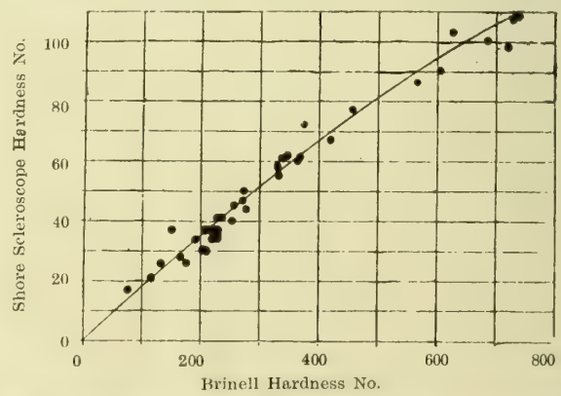


FIG. 7.—COMPARISON OF BRINELL HARDNESS NO. AND SCLEROSCOPE NO.

were kindly provided by Sir Robert Hadfield, who also undertook the hardening of the special wearing ring used for the tests. In addition, tests were also made on some samples of steel used for the manufacture of gauges and other material available at the N. P. L. for the purpose of the work.

The determinations made on these samples were as follows: (1) The Brinell hardness number for the unworn surface (calculated as described above). (2) The Brinell hardness number for the worn surface. (3) The scleroscope number for the unworn surface. (4) The scleroscope number for the worn surface. (5) The wear expressed as thickness of surface layer worn away in millimetres per 1,000 feet of slip. (6) The relative resistance to sliding abrasion or the reciprocal of the quantities in column 5. (7) Ratio of Brinell hardness number to scleroscope number. (8) Ratio of Brinell hardness number to resistance to sliding abrasion. The values are tabulated in the order stated in Table II.

The load on the wear ring at which these tests were carried out was the same as in the previous tests with the rolling abrasion tests, namely, 410lbs. The reason for using a high value of the load in the sliding abrasion tests was that, although a satisfactory rate of abrasion could be obtained with loads as low as 100lbs., the wear of the specimen was much more uniform when the higher pressure was used. At the low pressures there was a tendency for the specimen to become elliptical, so that the determination of the wear was difficult. The adoption of the high value, on the other hand, undoubtedly caused the relatively small hardening up of the surface of the specimen which was detected in a few instances under sliding abrasion.

(*To be continued.*)

MECHANICAL DESIGN OF ELECTRIC LOCOMOTIVES.*

BY A. F. BATCHELDER.

IMPORTANT features in the mechanical design of electric locomotives are, in the order of their importance: (1) Safety of operation. (2) Adaptability to service conditions. (3) Reliability in service. (4) Convenience of arrangement as affecting safety and efficiency of operation. (5) Power efficiency (affected by mechanical design). (6) Service time factor (ratio, time available for service to total time). (7) Cost of maintenance of permanent way. (8) Cost of maintenance of locomotives. (9) First cost.

Safety of Operation.—The steam locomotive has been developed to such a state of perfection that it can operate at near 80 m.p.h. with perfect safety; but no one would think of operating at this speed backwards. With the coming of the electric locomotive, the railroad operator is not content with single-end operation, but must have a locomotive that will operate equally well in either direction. This does not impose any serious difficulties in the design of locomotives for speeds under 50 m.p.h., but for higher speeds it requires very careful consideration of running-gear details, to obtain the most satisfactory results as to tracking and effect on rails and road bed.

The steam locomotive has now what seem to be natural characteristics to allow high-speed operation in one direction. These characteristics are low centre of gravity at the front end carried on the centre pin of a 2-axle guiding truck tending to prevent rolling over and having but little effect on the guiding, and high centre of gravity at the rear end with inside journal bearings allowing the locomotive to roll and increasing the time element, which thus reduces and distributes the lateral pressure against the rail over a longer distance and increases the vertical pressure on the rail, thus holding the locomotive more firmly in place. These same characteristics can be obtained in electric locomotives by the sacrifice of double-end operation.

The advantages gained in operating the electric locomotive in either direction are so important that means should be provided for satisfactory double-end operation. One way of doing this is by using a 4-wheel guiding truck at each end of the locomotive. With the use of the extra truck, however, the importance of a high centre of gravity largely disappears. The lateral pressure against the rail at the rear end now appears at the truck flanges rather than at the flanges of the driving wheels, and the high centre of gravity no longer provides the same increased vertical pressure on the outer rail at the point of the maximum lateral pressure. The lateral stresses from guiding the main frame being taken at the centre pin of the two guiding trucks, the additional vertical pressure on the outer rail is dependent upon the height of these centre pins rather than upon the height of the centre of gravity of the main frame above the wheel hubs, thus leaving less advantage to be derived from a high centre of gravity.

The paper shows that while the swivel truck is desirable as a guiding agent at the front end, it is not so desirable at the rear end, and means must be provided to prevent oscillation of the truck and to accomplish the same results as the high centre of gravity in a single-end locomotive. For this it is necessary to reduce the momentum effect and to reproduce the equivalent of the time-element factor and of increase of vertical pressure on the outer rail that is characteristic of the high centre of gravity single-end locomotive.

The momentum effect can be reduced by introducing resistance against swivelling, thus restricting the truck from oscillating from one side to the other of the track. The amount of this resistance is determined by the allowable amount that can safely be applied to the truck when leading. To reproduce the time-element factor, lateral movement can be given to the truck centre pin by any of the several methods for giving lateral movement to the leading truck centre pins on locomotives. However, the writer has obtained the best results with the method that is the nearest to constant pressure and dead beat, as it also tends to prevent oscillating.

To increase the vertical pressure on the outer rail, the centre bearing of the truck can be made wide, thus allowing the vertical component of the lateral pressure at the centre of gravity to be transferred through the bearing to the wheel, or, with the narrow centre bearing, the height may be made such that the lateral pressure at that point will result in an increased vertical component independent of the height of the centre of gravity.

It is the writer's opinion that the double-end locomotive, while its characteristics are different, can be designed for high speed with safety equal to the single-end locomotive, and this regardless of the height of the centre of gravity.

Adaptability to Service Conditions.—The electric locomotive, besides being required to operate in either direction, is often also required to be adapted for operating high-speed passenger trains and heavy low-speed freight trains over main-line tracks, to negotiate sharp curves, and to be easy on light track and bridge structures. With locomotives having geared motors, the requirement of operating the passenger and freight trains can often be met by changing the gearing to obtain the proper speed and drawbar pull. The running gear can be made with trucks of short wheel base and coupled together, the number of trucks depending upon the required weight of the locomotive for its maximum drawbar pull, and also on the allowable weight per axle. With such a design curves of very short radius can be operated over, and the weight per axle can be such as to allow operation over light structures.

Reliability in Service.—When the design is such that it is safe to operate at the required speeds and is proper for the curves and other service requirements, and liberal factor of safety is provided for the parts subjected to strain, reliability in service affected by the mechanical part of the locomotive depends mainly upon the bearings, their lubrication, and the method of power transmission from the motors to the drivers. It is necessary, therefore, to provide effective lubrication and as few bearings and as simple driving mechanism as the design of the motors will allow.

Convenience of Arrangement as Affecting Safety and Efficiency of Operation.—After providing all the safety appliances recommended by the Interstate Commerce Commission, it is important to arrange for the most convenient location of the operator to allow him an unobstructed view of the track and signals, to place within his easy reach the air-brake valve and locomotive signal device handles, as well as the reverse and power-controlled handles, keeping in mind the importance of making them so free from complication

* Abstract of paper read at the annual meeting of the American Society of Mechanical Engineers, New York, December 5th to 8th, 1916.

that the operator will require the least amount of thought to manipulate any of the devices and be left free to respond to signals and look out for emergencies. The arrangement for housing the electrical apparatus and its position in the cab must be governed largely by its design, but it is important to arrange it so that its operating parts are accessible and easy to inspect, and at the same time are protected against persons coming in contact with any live parts.

Power Efficiency.—The power efficiency as affected by mechanical design is governed largely by the type of traction motors. It is apparent that the gearless motor mounted directly on the axle allows the design of maximum efficiency on account of its few bearings and absence of gearing and moving parts. The gearless motor mounted on a quill and driving through springs to the wheels may be considered second in its possibilities for high-efficiency design, it having additional bearings and a greater number of moving parts. The single-reduction geared motor with its additional bearings and gear losses can be given third place in efficiency design; the single-reduction geared motor driving through gears and side rods to the wheels may be placed fourth, and the gearless motor driving through side rods and jackshaft to the wheels fifth.

Service Time Factor.—The service time factor is dependent upon the ability of the locomotive to operate under all service conditions and without undue strains, which requires a liberal design of its wearing parts. In addition to this it depends on the simplicity of design of the locomotive and the ease with which its parts can be inspected, adjusted, repaired, or replaced.

Cost of Maintenance of Permanent Way.—The cost of maintenance of permanent way can be increased or reduced by the design of the locomotive. The lowest cost is obtained when the locomotive meets its service requirements without undue strains, when the rotating parts are balanced, the weights per axle are suitable for the structures, a suitable equalising system provided to maintain the proper weight distribution, and provision made to protect against flange wear.

Cost of Maintenance of Locomotives.—The cost of maintenance of the locomotive is dependent upon safety of operation, adaptability to service conditions, reliability, convenience of arrangement, and the same items that enter into its service time factor. It is also governed by the same conditions as affect the maintenance of permanent way. The care with which the material is selected, the quality of workmanship, ease with which the parts can be inspected, adjusted, repaired or replaced, and simplicity of design govern maintenance cost.

First Cost.—This will depend largely upon the design chosen, but its importance, except at the time of purchase, becomes of little moment when taking into consideration the eight foregoing features. With two locomotives designed for the same service, the cost of the difference in efficiency and locomotive maintenance alone for one year may, when capitalised, amount to a considerable proportion of the first cost of one of the locomotives.

Too much importance cannot be given to developing to the utmost the mechanical part of the electric locomotive. From the present outlook, the locomotive for high-speed passenger service with gearless motor with armature mounted directly on the axle, and the locomotive for freight and switching service with single-reduction geared motor mounted on and geared to the axle, lend themselves best to simple design and low cost of maintenance.

In making these comments the writer does not criticise the work of any other designer. The conclusions he has reached are drawn from experience with his own designs of the various types referred to.

World's Output of Graphite.—Interest in graphite at present is widespread. According to the Canadian Mining Institute "Bulletin," the two principal forms in which the mineral is found are amorphous and crystalline, the former being very common. The world's production statistics for 1912, the latest available, are (in tons) as follows: Ceylon 36,660, Canada 2,060, South Africa 42, Austria 50,017, Madagascar 3,011, United States 3,835, Mexico 3,158, Korea and Japan 8,363, Germany 13,814, Italy 14,517, Sweden 87, Norway 285, France 661, giving a total of 136,510 tons.

PREVENTING THE CORROSION OF PIPE.*

BY F. N. SPELLER.

CASUAL observation will show very marked differences in the degree of corrosion of pipe in service. For instance, hot-water heating systems show practically no deterioration in service after 25 years, while low-pressure steam returns sometimes give trouble after 15 years' service or less. Galvanised pipe in hot-water supply systems, where the water is heated under pressure, lasts from about five years upwards, depending on the temperature and quality of the water and volume of flow. The last-named condition is also severe on iron and steel pipe. These few instances are the extremes, but are surely suggestive when we consider that in pipe carrying ordinary water under some conditions there is no apparent deterioration in a generation; whereas in other cases, the same grade of pipe is seriously damaged in a very few years.

Some years ago, when steel pipe was comparatively unknown and not fully developed, it was natural to question this material, but comparisons of the modern wrought iron and steel pipe in the same lines in service have shown beyond any question that where corrosion is found one material suffers on the average as much as the other.

It has been the custom of the writer to keep several service tests under way continuously for the past few years. In every case the co-operation of some local engineer or organisation is sought under whose immediate direction the test is conducted. One of the most recent to be completed may be described as an example of the method pursued in conducting such tests. This test was made in the Pennsylvania building, Philadelphia. Four standard grades of pipe of well-known manufacture were selected and four pieces of each taken at random and coupled together alternately so that the hot water passed through each sample at the same temperature. The pipe used in the tests was taken from the hot-water return line, installed in the form of a box coil October 27th, 1913, and was removed November 20th, 1915. The temperature of the water averaged 175° Fah. The calculated amount of water passing through the pipe was 5,000 gals. per day for 600 days. The average depth of pitting for the steel pipe was 0·0665, and for the iron pipe 0·0695. The inside of pipe is subject to peculiar conditions not to be compared with external corrosion, and the inside surface is particularly vulnerable in that protective coatings are difficult to apply, therefore more liable to be defective.

Consider for a moment the situation in a hot-water heating system and a hot-water supply system where the temperature of the water is about the same. It is evident that the water alone is not responsible for the results observed, but rather something brought in with the water. The hot-water heating lines have started to rust and then the action has apparently stopped, while in hot-water supply lines the action is continuous and rapid: so much so, that if the pipe does not fail by leaking it may be plugged up tight with the reddish hydroxide of iron. The only way to account for this accumulation of oxide of iron is through the oxygen in solution in the cold feed water, amounting to 6 cub. cm. to 10 cub. cm. per litre according to the temperature and quality of the water. This very small percentage of oxygen is apparently the measure of the destructive power of the water and accounts for the fact that a limited volume of water has no serious action on iron, whereas when this water is renewed continually, especially when heated, the results are liable to be most disastrous. It will be useful to consider the mechanism of corrosion before discussing ways and means for preventing this action.

All water supplies carry more or less foreign matter in solution. What are usually considered the purest natural water supplies are generally saturated with oxygen and carbonic acid, which cause such waters to be very corrosive, particularly when heated. Iron in all its forms is soluble in water to the amount of a few parts per million, depending on its composition and that of the water. In this paper, in re-

* Paper presented at the recent annual meeting of the American Society of Heating and Ventilating Engineers.

ferring to water in connection with corrosion, it will be understood to include domestic supplies of the usual degree of purity. Chemically pure water does not occur in nature, and therefore may be omitted from consideration.

The phenomenon of solution is now generally explained as an electro-chemical reaction. When pieces of zinc and copper are connected together and suspended in water, a current of electricity starts to flow through the water from the zinc to the copper. The zinc is termed the anode, and the copper the cathode. While the current flows the zinc goes into solution, the amount dissolved being proportional to the current according to Faraday's law. If we replace the zinc with a piece of iron, a current flows in the same direction and iron will be found in solution. Suppose we now replace the copper with another piece of iron. A small current of electricity will still flow, but not necessarily in the same direction, this depending upon the relative surface condition of the two pieces of iron.

It is this small current flowing between one piece of iron and another under water which causes iron to enter solution, and this is now recognised as the initial reaction of corrosion. Solution is hastened by carbonic acid and mineral salts in solution, as these make the water a better electrolyte. However, it has been proved that iron will dissolve to some extent in the purest water that has yet been made. If the iron is exposed to nothing but water this reaction will soon cease, due to the accumulation of hydrogen at the cathode causing polarisation; and this is what actually happens in practice in hot-water heating and other systems in which the water and consequently the supply of free oxygen is not renewed. On the other hand, when oxygen is present it combines with the hydrogen, depolarising the surface of the iron and thus causing solution of the iron to continue. Oxygen enters further into the reaction by combining with the ferrous hydroxide to form insoluble ferric hydroxide, generally known as rust. With an unlimited supply of water and oxygen, corrosion will continue until the iron is all converted into the form of ferric hydroxide.

So far most of the authorities are agreed as to the cause of corrosion, although there has been considerable scientific argument as to whether a trace of carbonic acid (CO_2) is necessary or not for the solution of iron. For all practical purposes we can let this question rest and combine the acid and electrolytic theories into one, as outlined above, which affords the best explanation of the observed facts available at this time.

Ever since the electrochemical theory of corrosion was proposed by Whitney in 1903 there has been a division of opinion as to the cause of the difference of potential observed between two pieces of iron. The majority at first assumed that this was due to variation in composition of the metal, and the manufacture of iron of a high degree of purity in the open hearth furnace was heralded with great expectations as to durability. So far, after several years of trial it has not been found that such iron is so well adapted for the manufacture of pipe as the grade of soft weldable steel now generally used for this purpose.

In the year 1904 the writer started a study of the potential differences as found on the surface of iron of various compositions, and has invariably found just as much difference in potential on the surface of very pure iron as on steel or wrought iron of ordinary commercial quality. Subsequent observations, covering several years of service with pure iron, open hearth and Bessemer steel, and wrought iron of the quality required for the manufacture of wrought pipe, have confirmed the conclusion expressed by the writer after his earlier experiments, namely, that composition has very little to do with the rate of corrosion of these metals under water. It should be remembered, however, that conditions of underground or inside pipe lines are not the same as they are when exposed, so that these conclusions do not apply to materials subjected directly to atmospheric conditions, such as metal roofing, which is another problem.

The tests and experiments referred to indicate that differences in finish and density of the material, particularly the character of the mill scale and how firmly it is attached, usually determine where corrosion starts and how it proceeds. The difference of potential due to surface influence was found to be many times greater than that due to variations in composition in the ordinary run of steel, and predominated over all other influences in nearly every case. These conclusions were tested in the most critical manner, and have since been borne out by service tests of several years' duration.

Among the surface influences which directed the course of corrosion it was found that rust, when once formed, was nearly as potent as mill scale in its effect on corrosion. Some recent work by Mr. James Aston, M.E., of the U.S. Bureau of Mines, confirms these conclusions, but goes further in showing that the influence of rust in some cases is to render the metal underneath the rust anodic. As the mill scale is always the cathode, there is every reason to believe that we may have in certain places on the surface nearly double the difference of potential which was expected and this without reference to the actual composition of the iron or variations thereof. Everything seems to point to this explanation of the cause of pitting as being the true one. Under some conditions of service in water lines or boilers it frequently happens that the tubes, which prove to be of a high standard of quality as regards chemical composition, structure, and physical properties of the metal, have rapidly pitted through in places. The difference of potential and the current which thereby flowed from the exposed places to the firmly attached mill scale, especially after the exposed metal becomes covered with rust, affords a satisfactory explanation of the rapid pitting observed in such cases. The current flowing between two points on the surface of a piece of iron is very difficult to measure accurately; however, we have frequently observed currents as high as one milli-ampere flowing between steel electrodes in McKeesport city water, one plate being clean and the other covered with mill scale. Some typical readings between plates of the same area made with a milli-ammeter having an internal resistance of eight ohms are shown in the table below.

Electrolyte, McKeesport City Water.

Submerged area of plate in square inches.	Current in milli-amps.	Current divided by the square root of the area of plate.	Distance between plates.
0·155	0·07	0·18	1
0·338	0·10	0·16	1
1·643	0·25	0·20	1
3·875	0·48	0·24	1
16·430	0·98	0·24	1
0·062	0·06-0·09	...	$\frac{1}{8}$
0·342	0·14-0·18	...	$\frac{1}{8}$
16·430	2·02	...	$\frac{1}{8}$

It might seem at first that these currents are too small to cause serious damage. A rough calculation based on these experiments will indicate the ultimate result from such currents acting continuously with certain submerged areas of electrodes. One ampere acting for six months will dissolve 10lbs. of iron or a plate 12in. by 12in. by $\frac{1}{4}$in. One milli-ampere acting for six months will dissolve 0·144 sq. in. of this plate, making a hole about $\frac{7}{16}$in. diam. by $\frac{1}{4}$in. deep. On the other hand, 0·1 milli-ampere acting for 60 months will perforate this plate with a hole of the same size. This rate of pitting is not so far different from that experienced under some conditions of service. The remedy seems to lie in the elimination of dissolved oxygen from water before use. This may be accomplished in practice in at least two ways, by allowing the hot water to come to rest for a few minutes under greatly reduced pressure, or by fixing the free oxygen. As no reliable data could be found on the amount of oxygen retained in solution in water at various temperatures and pressures, a series of experiments were run to determine these constants. Evidently the pressure must be reduced below normal or the temperature raised nearly to the boiling point with the water at atmospheric pressure to get proper separation of oxygen and other gases.

An alternative method of reducing corrosion in water lines by satisfying or "fixing" the free oxygen was tried out by the writer several years ago, using clean iron turnings. It was found difficult to get the scrap free from oil, and after rusting had progressed for some time there was a tendency for the mass to cake together and so impede the flow. By using sheet iron, so formed as to provide a large number of

channels with about ¼in. clear passage through which the hot water slowly percolates, we expect that these difficulties will be overcome. The rate of rusting varies with the surface condition of the plates, becoming more rapid as the surface is covered with a good coating of oxide. The speed of rusting is 50 per cent. more rapid at 110lbs. per square inch pressure than at atmospheric pressure, and, of course, the time required to "fix" the free oxygen of the water varies with the amount of surface of metal exposed per cubic foot and other conditions, which are liable to vary.

On this principle, two small plants have been equipped to carry out this method of treatment in practice. These systems were installed at places where considerable trouble has already been developed through the clogging and corrosion of galvanised pipes. These plants, which have only been operating a short time, show a reduction of oxygen contents from 8 cub. cm. or 9 cub. cm. per litre to 0·1 cub. cm. to 1 cub. cm., per litre, according to the rate of flow and temperature. At present it seems desirable to design the plant so that the oxygen contents will be less than 1 cub. cm. per litre at all times, at which point corrosion seems to be reduced to a negligible amount. Some more definite data on this point will be available after these plants have been in operation for several months. The indications are that the rate of rusting of the plates, and hence the efficiency of the apparatus, will increase with time. Water should be in contact with the plates for at least ten minutes.

Similarly, the corrosion of low-pressure steam lines will be found to depend principally on the amount of oxygen which finds access to the system. The return lines naturally suffer the most, and are usually the first to show failure. Condensed water, when freed from oxygen in solution, is harmless, and will not even tarnish bright iron after months of exposure; but this water, on account of its great purity, has greater capacity for solution of oxygen than the average natural water, and is therefore apt to be very corrosive when aerated. This may be prevented in large measure by using an open feed-water heater and keeping the water over 185° Fah.

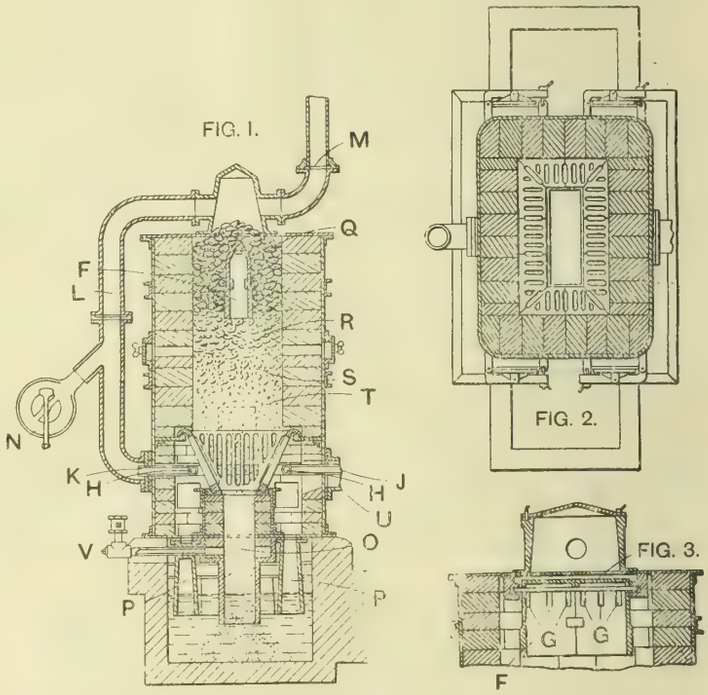
In some cases the surface of the pipe may be protected with a film of oil deposited from the steam. The writer's attention was recently called to the satisfactory results obtained in some buildings using exhaust steam which on investigation was accounted for by the thin film of oil found on the inside of these pipes. This was such an interesting matter that we made some tests in the research laboratory on long lines of new pipe, and found that mineral lubricating oil, when dropped into a pipe carrying steam under pressure at the rate of two drops per minute, was carried forward in a fine state of division, and in a few minutes was found condensed in a uniform film in the pipe about 160ft. from the lubricator. While this simple means of protection would perhaps be objectionable in some cases, there are many steam heating systems where the oil could do no harm, and might result in considerably prolonging the life of the lines. Of course, nothing but a good grade of mineral lubricating oil should be used, and the supply should be regulated by a reliable sight feed lubricator.

Summarising very approximately the influence of various factors on corrosion, it appears from the experience we have at present that developments in the metallurgy and manufacture of steel pipe promise to add 50 or perhaps 100 per cent. to the life of pipe compared with the service obtained under like conditions 10 or 12 years ago.

Graphic Methods for the Solution of Electric Railway Problems.—In an effort to overcome the difficulties attendant upon the use of analytical methods in the solution of electric railway problems involving the characteristics of motive power, A. M. Buck, of the Engineering Experiment Station, University of Illinois, has developed a series of graphical methods which supply an accurate and easy means of attack applicable to any possible combination of electric motor characteristics and any range of conditions which may be met in practice. Diagrams have been developed to set forth the relationship between motor current and speed, between current and tractive effort, between speed and tractive effort, between speed and time, &c. The results of Prof. Buck's studies are set forth in Bulletin No. 90 of the Engineering Experiment Station.

NELSON'S GAS PRODUCER.

WE illustrate herewith a design of gas producer, the invention of Mr. Lionel Nelson, Hunter Street, Wellington, New Zealand. Fig. 1 is a vertical section and Fig. 2 a sectional plan of the producer; Fig. 3 is a section through the top of the generator at right angles to the section shown in Fig. 1. The generator is of rectangular section, with an air distributor F, also of rectangular section, so that the sides are as nearly as practicable equi-distant from the sides of the generator. This air distributor has its upper end covered with a reversed V-shaped roof, and near the top of its sides it is provided with air passages G to admit air within the pipe from an air supply above. It has a large outlet at its lower end, which allows air to pass down through it at a low rate, so that no intense local heat is caused which forms clinkers. The air distributor is of sufficient depth to reach to or a little below the surface of the incandescent mass, and is arranged in the distillation zone of the producer, and above the combustion zone. It serves the double purpose of introducing



NELSON'S GAS PRODUCER.

gas to the combustion zone, and so regulating the feeding of the furnace with coal as to automatically "trim" the fuel, thereby creating natural air ducts at each wall of the producer, in each corner, and also down the centre of the fuel bed. The steam for mixing with the air is supplied from a vaporiser tube comprising a part H, which surrounds the grate, and lateral extensions J and K, the former ending outside in a syphon water seal, and the latter issuing into the pipe L, the upper end of which communicates with the top of the generator, a damper being arranged at M. A fan N is branched on to the pipe L for the supply of air to the generator.

Brick pedestals support the grate, which has an open bottom, through which clinker falls or may be poked down, and thence through a discharge pipe O, and can readily be withdrawn through a water lute, which prevents air entering the bottom of the generator and mixing with the gas. Any ashes that fall through the sides of the grate pass down through the ash pipes P into the water seal. The grate, being cone-shaped, forms a larger area than a flat grate, facilitating the downward passage of the gas out through between the bars. The distillation zone Q, the combustion zone R, the reduction zone S, and the ash zone T are shown approximately in their respective positions.

The generator, which acts on the down-draught principle, is operated as follows: When the plant is working with the damper M closed, the air is fed to the producer by the fan N and the pipe L. The necessary steam is produced in the

vaporiser H, the steam issuing through the open end of the vaporiser, and discharging into the lower end of the pipe L. The steam is drawn along pipe L, and mixing with the air supplied through the fan N is introduced into the top of the producer, and thence through the fuel and slotted holes round top edge of air distributor F to the centre of the combustion zone. The gas on its way downwards passes through the incandescent zone, the reduction zone, ash zone, and furnace bars, and issues from the generator through the passages U, discharging thence into the scrubber. In the process of combustion the tar is driven off in the form of vapour from the fuel at the top of the fuel space in the generator, and is drawn or driven through the bed of incandescent fuel beneath. The tarry vapours meet in this incandescent fuel with a supply of air or air and steam, which is supplied through the distributor F at the depth above referred to, which ensures the combustion of these tarry vapours, and renders them innocuous. The tarry vapours are partially driven off upwards under the slight pressure due to the heat in the combustion zone, and mingle with the air, and pass down with it through the distributor F, as this is the path of least resistance, thus ensuring thorough mixing before entering the incandescent zone, and causing a very efficient combustion. The tarry vapours that do not pass through the distributor pass down with air outside the latter into the incandescent zone, and are there consumed. In the event of any partially-consumed fuel finding its way into the ash duct, or when, due to faulty operation of the plant, the fire zone has crept too high up in the producer, air may be admitted below the grate through the auxiliary pipe V, in order to blow up the fire, and has the effect of lowering the fire to its proper level.

ALUMINIUM CASTINGS AND FORGINGS.*

BY P. E. MCKINNEY.

IN the manufacture of light castings the following properties might be cited as most desirable: (*a*) Low specific gravity; (*b*) a fair amount of strength and freedom from brittleness; (*c*) good machining properties; (*d*) the maximum resistance to corrosion; (*e*) good casting qualities and freedom from hot shortness.

It is a well-known fact that pure aluminium is entirely too soft to produce satisfactory castings for most purposes, and it is the universal practice to stiffen up the alloy with some hardening element. Probably the most widely used hardener for aluminium is copper, which is used at the rate of about 8 per cent. of copper to 92 per cent. of aluminium. Zinc and tin are also frequently used as hardeners. The use of these hardeners is attended with some well-recognised objections. In the first place the addition of from 8 to 10 per cent. of hardener partially defeats the purpose of using aluminium, in that the specific gravity is materially increased. The hardened metal, while fairly strong, has a strong tendency to brittleness, and the alloys are in most cases less resistant to corrosion than either of the component metals. Hot shortness in the case of intricate castings is another feature attendant to the use of these hardeners.

In the ninth annual report of the Alloys Research Committee, Dr. W. Rosenhain and F. C. A. H. Lantsberry have published some very interesting data on the influence of manganese on aluminium alloys, which demonstrates beyond a doubt that these combinations have great promise in the production of light alloys. Various combinations containing manganese with or without copper and with a minimum aluminium content of 95 per cent. have been used in actual foundry practices for the last two years with the most gratifying results. The use of manganese in relatively small quantities hardens and strengthens the alloy without destroying its ductility as is the case with copper or zinc. The machining properties are excellent, and the comparatively small amount of hardener used makes possible a specific gravity in the finished alloy from ·35 to ·40 less than that of the ordinary No. 8 alloy. When properly made these alloys are practically free from hot shortness, and the most intricate castings can be produced with comparative ease.

* Paper read before the American Institute of Metals.

The statement has frequently been made that for the successful production of good aluminium alloys it is necessary to have available special melting furnaces and devices for handling the metal. This has not been found to be the case in handling the alloys of aluminium containing manganese, which can be melted in natural draught pit furnaces, provided ordinary precautions are used in melting and fluxing the metal. The most satisfactory method of introducing the hardening elements is first, by alloying them with a small amount of aluminium, making a rich hardener of definite proportions and comparatively low melting point.

The most dangerous impurities encountered in aluminium alloys are carbon, silicon, and iron, hence the greatest precaution should be taken to prevent introduction of these impurities either in the metal used or through the medium of crucibles and tools. With this in view carbonless manganese produced by the Thermit process has been used exclusively for this purpose. This is alloyed with copper when aluminium-copper-manganese is being made by melting 60 per cent. copper and introducing 40 per cent. of manganese in small pieces, heating until the two metals have combined, which is seen by the smooth condition of the surface of the metal. This alloy can then be diluted with an equal weight of aluminium to reduce the melting point, although it is perfectly feasible to use copper-manganese direct. In making the alloy of manganese without copper 80 per cent. aluminium is first melted, brought to a bright cherry red, and 20 per cent. manganese added in very small pieces. The alloy should be poured as soon as the manganese is all dissolved.

In melting aluminium alloys clay crucibles or clay-lined crucibles are preferable. No charcoal or carbonaceous covering is used on the metal, as carbon combines with this alloy, forming a very brittle compound. Gates and sprues from castings must be carefully cleaned and freed from sand, as practically all the sand introduced into the pot is reduced to silicon, which materially weakens the alloy. In cases where there is danger of introducing sand into the crucible, it has been found very beneficial to introduce a powdered flux, which is made by melting together 60 per cent. of potassium chloride and 40 per cent. of kryolite, and powdering the mixture. This flux tends to dissolve the silica and keeps it from combining with the aluminium.

In preparing the alloy for casting purposes an empty crucible is set in the furnace and heated to a bright red heat. The requisite amount of hardening alloy is added and melted as quickly as possible. As soon as the hardener is melted the draught is cut down by opening the cover of the furnace and aluminium is added in small increments as fast as it will melt, timing the additions so as to keep the temperature of the mixture at not more than a faint red heat. The crucible is drawn from the furnace just before the last of the aluminium is melted in order to prevent the metal becoming overheated. This is a very important point, as overheated aluminium will absorb silica from the walls of the crucible at a very rapid rate, and it has been found that once overheated this aluminium is practically worthless for future use. Just before pouring there is added to contents of crucible about one-fourth ounce zinc chloride, and the metal is thoroughly stirred with a clay-covered skimmer. This zinc salt tends to reduce the oxides and dross in the metal and puts it in ideal condition for casting purposes. Alloys of aluminium containing manganese have a slightly greater shrinkage than those containing copper alone, and due allowance must be made by using ample risers and chill plates on intricate castings.

The elastic ratio of this alloy as determined by the drop of the beam of the testing machine will average about 60 per cent. of ultimate strength. The fracture of test specimens is silky and shows considerable toughness instead of being granular and brittle, as is the case with many aluminium alloys. Castings are practically free from hot shortness, and it has been found to be perfectly feasible to make castings with very thin webs without any trouble due to this cause. Alloys of aluminium containing manganese have been found to work very freely either by cold rolling or hot forging, and many intricate shaped drop forgings have been produced by its use.

The following are results of tensile tests of coupons

from sand-cast aluminium castings taken at random from recent heats:—

Manganese, 1·50 per cent.; copper, 2·00 per cent.; aluminium, 96·00 per cent.

Tensile Strength, lbs. per sq. in.	Elongation, per cent. in 2in.
22,000	15·0
22,000	14·0
21,000	8·0
19,000	9·5
19,000	14·7
19,000	14·0
21,000	13·0
22,000	12·0
24,000	10·0
19,000	12·0
18,000	13·0

In preparing the alloy for forging purposes the same precautions are observed in melting and pouring the ingots as in the case of sand castings. The same type of ingot moulds as are used for bronze forging ingots are suitable for aluminium. The ingot moulds are heated to about 500° Fah. and given a thin coating of orange shellac to produce a clean skin. The metal should be carefully skimmed and poured very quickly in order to prevent cold shots due to the low temperature at which it must be poured.

In making drop forgings from aluminium a little preliminary forging is very desirable. The ingot can be cut or cropped to the desired lengths and forged to approximate shape at a temperature of from 1,150° to 1,400° Fah., after which they can be finished in the dies. These alloys flow with ease during forging, and dies have been found to fill very nicely in all cases. Forging dies of the same type as are used for tobin bronze forgings are perfectly satisfactory for aluminium work.

The stiffness and strength of the forged material can be controlled by varying the finishing temperature. Considerable stiffness and elasticity can be imparted to the forgings by two or three blows of the forging dies at about 500° Fah. The following are typical physical properties obtained on bars of this alloy forged to 1in square, and turned to standard size tensile specimens.

Soft alloy containing: Manganese, 1·00 per cent.; copper, 2·00 per cent.; aluminium, 96·50 per cent.

	Tensile Strength.	Yield Point.	Elongation.	Reduction.
Cold finished ..	27,750	27,750	12·00	47·00
Hot finished ..	21,083	12,223	26·7	48·7
Intermediate ..	25,617	22,918	17·4	52·00

Hard alloy containing: Manganese, 2·00 per cent.; copper, 3·00 per cent.; aluminium, 94·50 per cent.

	Tensile Strength.	Yield Point.	Elongation.	Reduction.
Cold finished ..	31,930	30,000	9·75	35·3
Cold finished ..	34,123	33,000	4·00	11·25
Cold finished ..	30,405	30,000	11·25	30·78
Hot finished ..	27,450	15,000	21·95	56·0
Intermediate ..	28,670	22,000	21·00	50·4

Sections cut from thin drop forgings which were cold-finished have shown tensile strength as high as 40,000lbs. per square inch. The forged material machines very nicely and shows a fine silky fracture when broken. The increased density of the metal produced by forging makes it a great deal more resistant to sea-water corrosion than the cast alloy. Several drop forgings of these alloys are now undergoing service tests on ships at sea to determine their resistance to corrosion and reports thus far received are very promising. Considering the low specific gravity of these alloys together with the strength and ductility obtainable the material compares very favourably with the heavier bronze and brass forging materials for many purposes.

THE ECONOMIC OUTLOOK AND THE LABOUR PROBLEM.*

BY F. W. LANCHESTER.

(*Concluded from page 488.*)

I HAVE said that behind the men's doctrine of restriction of production there is something more than is apparent on the face of things. The true reason why the doctrine of restricted output has found so much support amongst organised labour is that although restricted output is demonstrably injurious, and to be regarded as the curse of the country, of the Nation and the State, the particular trade to which the men's organisations have applied restriction have sometimes been seen to flourish like a green bay tree, at least as gauged by the prosperity of the wage earner. The reason for this is simple. Take the bricklaying trade, for example; in this I am credibly informed that the maximum number of bricks which it is permitted for one man to lay is one-third of what a man can lay and one-tenth what, with a little organisation and assistance, a bricklayer by way of record has laid. Now in this trade there is a monopoly, free trade or no free trade we cannot import houses whole, so that if the bricklayers decide that they will have a certain weekly wage for laying a certain number of bricks, and if they by force or persuasion can prevent so-called blacklegs from coming in to do the work, they are able to enforce their own terms. Let us suppose that their wages are increased 50 per cent. and the number of bricks they lay is half of what they would have laid under unrestricted conditions. Their standard of living increases at a bound by 50 per cent. But, from the time of the combination forward, every man building a house with bricks has to pay three times what he did before for the laying of the bricks, and every man who lives in a house so built has to pay three times as much rent on that particular portion of the cost of the house as he otherwise would. So far the resulting difference is not noticeable amongst the community at large, just as it would not be noticeable if I received a penny per annum from every man, woman, and child in the country, the country would not be perceptibly impoverished, but I should become a millionaire. So in the case of the first trades union to organise, the impoverishment of the country is not perceived, but the workers in that particular trade are able to live like fighting cocks.

But the same does not continue to apply when trade after trade becomes organised. It is evident that if every trade and every worker in the country were to do the same as my imaginary bricklayers have done, there would be a shortage in the total production, and as it would be expressed the cost of living would have gone up more than the wages. Is not this just what was being discovered prior to the war? There had been an investigation as to the cost of living, and during the period under investigation it transpired that the cost of living had gone up almost exactly to the same extent as the rate of wages. Precisely what ought to have been expected, and yet the attitude taken by the men's leaders was that the employer having been made to pay what by some process of thought was described as a "fair or living wage" and had been forced to grant better conditions of employment, the scoundrelly capitalist had put the prices of things up so that the working man was no better off than before! One cannot seriously hope for a great deal when this type of thought obtains currency.

But the worst has not been said. The most serious detrimental consequence, so far as the State is concerned, is the fact that there is a number of trades, perhaps a minority, which cannot organise without extinction. They are trades in which low-priced labour on the Continent and cheapness of transit permit of keen external competition. Those employed in such trades find themselves receiving wages on, if I may say so, the old or lower scale, that is to say, the scale before the inflation due to the big labour combinations. But on the other side of the ledger they may have to pay rent on houses built by men of the bricklayer's union, men of the plasterer's union, almost every other portion of the house has had to pay wages on the enhanced basis. When

* Abstract of presidential address delivered before the Junior Institution of Engineers, December 11th, 1916.

they buy bread it is baked by men who belong to a union, and so forth. It is quite true that many of these unions have never seriously upset the natural conditions of labour, that is as regulated by the law of supply and demand, but on the other hand in many cases this is not so, and there is no doubt that to-day these unorganised and unprotected industries, paid on what I have referred to as the lower scale, are having to buy half the necessities of life on a scale to which their own wages do not in any way correspond. It is unnecessary to catalogue a number of these trades, but the East End clothing trade is an example. The term of opprobrium "sweated" labour is commonly used in connection with these trades.

As I see it, therefore, the present-day trades unionism in its most aggressive form is inimical to the country's welfare. Put bluntly, it consists of a conspiracy of persons to hold up industry for their own personal gain and benefit. What before the days of the modern phase of organised labour was the recognised factor in the payment of different industries? It was the natural law of supply and demand. If, for example, an expansion took place in any given trade there was a demand for labour, and the wages stood at a relatively high figure. Any man in an analogous trade who thought he could change with advantage would endeavour to do so, and there were no serious obstacles in the way. Any man who had sons to place in a trade of some kind would look round him and, other things being equal, would choose that trade which appeared to have the best prospects of remuneration and the best assurance of employment. In this way there was an equilibrium between one trade and another, and one could say that, ignoring the slight inequalities of employment from time to time due to the adjustments in course of progress, the rate of pay in any trade would be comparable to any other trade in the same district, if account were taken of the relative hardships experienced or the relative difficulty or skill required in the work. Is this condition still allowed to continue? The answer is no. Many of the trade organisations have put, and attempted to put, restrictions on the entering of their trade in order to artificially maintain their own position. It is, I think, evident to any fair-minded man that the fact of such restrictions being necessary—they are not merely restrictions to prevent unskilled persons coming in—in itself implies that the union has created an exceptionally favourable position for its membership, and bears out the contention that it is in fact levying a tax on the community.

My own belief is that the rank and file of the workers do not know exactly in what manner their policy of restricted output operates, they are not conscious of the fact that in drawing a given wage for a restricted output they are doing their fellows an injustice. It only comes home to them eventually, when they find that other trades have done the same, and that when they are buying the goods they have to pay a higher figure. Even then I do not suppose they realise, if they happen to be members of one of the earlier unions, that it is merely tit for tat, that they have been putting the price up against somebody else, and now somebody else is returning the compliment. The reason for this ignorance is, I think, to be attributed to the very indirect way in which the increases in the cost of production finally affect the consumer. It is commonly a roundabout path of great complexity. For example, the boiler maker gets higher wages, the price of boilers increases, the man who buys a boiler pays a high figure, and his boiler, both as a capital charge and in depreciation, stands higher on his books. His product, which may be machine tools, becomes affected and his machine tools sold to another firm stand at a higher capital charge and a bigger depreciation item, and so on. The final item bringing the matter home to the consumer may be fourth or fifth hand, and the classes of consumer may be widespread. In addition to this, of course every small increase does not produce an amount which can be recorded in the selling price of an article, so that several trades might become organised, and the cost of articles might increase without the consumer being saddled with it till some considerable time afterwards. A selling price usually goes up in jerks, whereas the production price may go up in infinitesimals. There is a big cushion between cause and effect in the "reserves" of companies, the temporary reduction of dividends, &c., but sooner or later the fundamental economic fact asserts itself, that the community cannot consume what they do not produce.

I have dealt with the economic aspect of the subject at considerable length because I think that great benefit would result if the economic side of the question is understood clearly by those upon whose brains and skill the future of our industries so largely relies. The greatest hope for the future that I can see is that the country at large may become alive to these broad questions of economics. I am sure that, if the country were better informed on this subject, it would go a great way towards checking the fallacies which I have done my best to expose. I confess that one's hopes and ardour are somewhat damped when one meets people who talk glibly of the fact that "money must circulate," as an excuse for extravagance, as if the circulation of money makes the individual prosperous or the country wealthy. There is also the widespread fallacy, that of the philanthropic person, that the only way to "do good" with money is to go out of their way to organise a means for its consumption. They seem entirely unable to grasp the fact that every £300 spent in this way means one less working man and his family in Great Britain for a given standard of living. They rarely reflect whether they might not be doing more good by investing their money than by spending it, often in a worthless or lost cause. There are many inexperienced people who have inherited wealth in which they have taken no part in accumulating and who believe they are doing good by dissipating it in various ways which are sometimes worthy and sometimes are not.

Finally, there is the extraordinary unpopularity of a man who saves and invests money, who is alternatively described as a miser or a Jew; it may be that the man who so describes him is working under a roof made by that same "miser's" invested capital, and earning his living by the aid of an implement which that self-same miser's frugality and self-denial have enabled him to place at his disposal. It is the mighty strength of the much-abused system of capitalism that the self-interest of the individual is commandeered to supply the needs of the State; the inducement being a few per cent., frequently no more than 3 or 4 per cent., on the invested capital. The value to the State of this invested capital as represented by the increased powers of production of labour far exceeds the dividend drawn by the man who has found the money. But it is the custom to refer to the capitalist as if he were some kind of species apart; a form of vampire which is living on the blood of the people. As a generalisation he is in a minority, I believe that the late Chancellor of the Exchequer used to refer to him as 10 per cent. of the total, but he is not a class by himself, any skilled worker who, making full money sometimes in his 'teens and at least in his early twenties, saves what he easily can save, will before middle age become a capitalist, to the full extent to which he employs capital, in other words he may easily accumulate a sum of £200 or £300. If every skilled worker were to do this in one generation we should no longer hear talk of the capitalist as a class, and in two generations he could virtually own the assets of the country.

It cannot be too strongly insisted that our capital is not entirely, or even mainly, in the hands of a class who are not workers, in many cases, and I believe in most cases, the investor is quite as hard a worker and an apostle of labour as those in the artisan class who arrogate to themselves that title. The probability is that the thrifty will always be in a minority because human nature is what it is, and as I have heard it expressed over and over again when discussing the subject with manual workers and others, "Well, sir, what is the good of saving it, you only live once." It is a fact, not without interest, that the Jewish nation have an extraordinary gift for saving. A typical Jew does not save simply because he has a big income, he begins to save if he has only a few shillings a week, and this fact is true of a great number of those others to whom the increase of capital is due. The financial and industrial status of those countries in which the Jew has been subjected to persecution is almost invariably lower than those in which he has been hospitably received. This may be taken as a simple illustration of the fact that the man who saves is a benefactor to the State.

So far as the material enjoyment of life is concerned, and the standard of living, the possession of wealth which is invested and of which the interest is reinvested does not matter one iota. This is a fact which is curiously neglected in the

public appreciation of the wealthy man. Consider, for example, any man who comes into the world comparatively poor, and lives an ordinary, and from a modern standpoint frugal life, who is industrious, who saves money. In his ledger account with the nation we find his cost in education, and some property or wealth he inherits, on the other side we have the fortune he leaves. Presuming that his money has been made by industry and not trickery, the balance of this account is the extent to which he stands a benefactor to the nation. He may leave his money to a son, if the son follows in the footsteps of his father, again at his death he in turn will stand as a benefactor to the nation. These men are benefactors as definitely as if the money were paid into the exchequer of the nation. If, in the course of inheritance, the money is lost or dissipated in what is by tradition termed "riotous living" it does not one jot detract from the benefits which were originally given, it is the business of the State to see that it is not defrauded and that the country's wealth is not misused even in private hands. It is my belief that it is in this direction that legislation should tend, in the suppression of useless luxury and the taxation of what we may call reasonable luxury, these things do not bring wealth to the country and they are a source of national leakage. It is only possible to act in this direction within limits, for the man who saves and through his individual capacity may build a fortune is entitled to say, "If I have bargained for the joint, may I not cut a morsel off the spit." Like the others he only lives once.

It is one of the current fallacies, and one may almost say tenet of the labour agitator, I will not say the labour leader in this case, that any man who makes money or makes a fortune as an employer or in any similar capacity in industry has obtained his wealth at the expense of the wage earner. It is not unusual to take, for example, some notorious company promoter or stock exchange gambler, where, literally, there may be much truth in the allegation. But it is very few amongst those who have not actually taken a part in the management of some industrial concern, who realise how easily a potential profit may become a loss due to bad management. The skill or industry of the artisan or manual worker is by no means the whole factor, and in the direction of his labour, quite apart from any act of invention of greater or less degree, there is room for various degrees of skill and for the exercise of different degrees of foresight. Careless or defective work in the engineering department, or in the costs department, or in almost any other part of the factory may result in the wastage of the fruits of labour. To a still greater extent may a miscalculation or imprudent forecast of a season's trade be disastrous to the efficiency of the combination of master and man. Let any artisan worker remember that the loss to the country due to any misdirection of his labour is just as clean a loss as if it were deducted from his own wages. If any losses due to inefficient management were actually deducted from his own wages he would find it in every way to his interests to obtain, if need be, at much higher prices than are current to-day, the best brains in the country to ensure that his labour was applied to the maximum advantage. The fact that his labour undergoes no reduction, even though it may be wholly lost by bad management, does not make it any less an act of true economy to pay a high price for efficient management. The fact that our industrial system virtually acts as an insurance against this risk should not blind labour to the fact that, whatever his own value may be, the value of the man who has the gifts and capacity to accurately gauge the conditions of the trade, and the men who are able to make every hour of labour tell to the best advantage in the production of an implement for a given duty is far greater, inasmuch as the gifts required are, in human experience, less widely distributed.

I have no panacea or recipe to offer in the matter of dealing with this complex labour problem. It is my personal belief that some reversal or modification of the policy of recent legislation will become necessary. One cannot be blind to the gravity of the position, since no legislation of a character tending to limit the power of the trades union is possible without the general consent of the electorate, in fact, one may say, unless with the mandate of the electorate. If one holds the view that logic must ultimately prevail, perhaps a majority may in time be found for the freeing of the wage earner from the shackles of restricted output. In any case, where a minority is able to benefit by any course of action at the expense of the State there is a primâ facie case for legislative intervention. In the present address I have endeavoured to make clear the fact that such a condition of affairs exists, or, at least, existed in the pre-war period, and in a greater or less extent to-day. Whether we shall get any Government with a conviction that this is true, and if we get that Government, whether it will have the courage of its convictions, are riddles to which I have not the key. I can only assert my belief, that for the sake of the country, for the sake of the wage earner himself, and for the healthy development of trade organisation, legislative intervention will have to come sooner or later. In the meantime, before public opinion is ripe, there is considerable hope that the worker himself may be led to take a broader view of his own true interests, of the nation's needs, and of his obligations to the State; this hope is certainly supported by the way in which, on the whole, he has risen to the occasion in the matter of munitions output. It is, however, always difficult by a mere process of moral suasion to undo an evil which should never have been allowed to grow up.

The whole situation is admittedly full of complication, different employers have different methods of their own of stimulating production, and, if one may say so, of dodging the restrictions which the trades unions have endeavoured to enforce. There are advocates of a straight piece-work system, and of various bonus schemes; there is something to be said in favour of each. So far as my personal experience goes, neither the one nor the other is really effective as combating the restriction of output; in some cases it would almost appear that there is a secret organisation within a works to fix its own times and prices on everything, so that although, nominally, the piece-work system gives every inducement to the employé to obtain an increased output in practice its whole purpose is frustrated. There are many difficulties also in the administration of a piece-work system. It sounds plausible enough to say that if a piece-work rate is set and a man can improve upon it the piece-work rate should never be altered. If the rate is reasonably and properly fixed in the first instance, and the means of production remain the same, then if the employé can make more than a customary wage by his industry, the cutting down of the piece-work system is both unjust and foolish. But it is difficult and sometimes equally unjust to maintain a piece-work price which either has been wrongly set in the first instance or has become obsolete because of a change of conditions. If in the performance of some one process a man is able to make three times his standing rate, whereas another process will only allow one and a half times the standing rate, and if no readjustments are permitted, it cannot be other than an injustice that two men of equal industry, skill, and ability, engaged, and working under the same conditions, should receive one double of what the other receives. Beyond this, is it not a danger to put into the hands of foremen or chargemen what amounts to the exercise of valuable patronage; we know the evils to which such a situation may give rise.

There are certain employers of labour, and many would-be social reformers, who believe they see the solution to the present industrial difficulties in schemes of profit sharing. The unsoundness in my opinion of the profit-sharing schemes such as have hitherto been proposed, and introduced in certain special instances, is due to the fact that the rank and file of the working community cannot afford to gamble. In any trading concern the first charge, if one may say so, on the finances is the wage bill, whatever else happens this must be paid, the most speculative and last charge on the company is the dividend. Now if profit-sharing were widely introduced into our industries, we should have in a number of factories men doing identical work, or work demanding equal skill, and doing it with equal industry; in all factories the men would be receiving some standard rate of wage as a basis; in one factory where big profits were made the men might be doubling their rate of wage, in another factory where no profits happened to be made the men may be getting nothing in excess of the minimum. Such risks are risks to which busi-

ness men and investors, as a class, are accustomed; they constitute what is truly termed the gambling risk in any business or investment. It is admitted on all hands that for the working classes a gambling risk is undesirable, it is far better that the working man should know what his weekly payment will be, or at least, where it is variable that it shall be a matter to some extent under his personal control.

It seems sometimes to be assumed by the less well-informed advocates of profit-sharing, as against other methods of encouraging industry, that the rank and file of labour would draw a share of the profits in addition to what he now receives. Even were it so adjusted in the first instance, the very laws or economic considerations which, at present, act to limit the wage equivalent, would soon bring the average down; it may be pointed out that even were this not the case, it would come off the existing dividend account of the country, and so would lower the saving power of the nation, which, as we have seen, is inadmissible whether viewed from the point of view of the State or the point of view of the worker himself.

The whole psychology of the manual worker is against allowing him to shoulder any of the gamble. If he is to have an increase in his pay, rather than profit-sharing, it should be on a piece-work or bonus system where the individual effort gives individual recompense. If under a profit-sharing scheme a district were to enjoy exceptional prosperity for a time, as nearly always happens in every trade, we know as a human certainty that the standard of living would go up, just as it has in the prosperous munitions districts to-day, and when the nearly inevitable slump arrives great hardships would be inevitable; in many cases the whole working-class community would be better off if they had not experienced the period of abnormal success. If the rank and file of labour could accept the gambling risk without danger there would be little or no need for our present betting laws, &c. Even amongst those who have had the advantage of a more liberal education, and leisure, and opportunity to look around them, a period of inflated prosperity does not always turn out to be an unmixed blessing. It has been the undoing of many a man in a good position.

The industrial engineer of the future will, without doubt, have his due measure of technical problems and difficulties to face; but it behoves him to watch carefully the wage earner's position and aspirations, and to find means to encourage him to co-operate in the campaign for industrial efficiency. Above all, it is necessary that the manual worker should be more fully instructed concerning those broad economic questions and principles against which he has in the past thrown himself in vain, in opposition to his own true interests, and to the disadvantage of his fellow workers, the nation and the State.

This educational influence cannot, unfortunately, be exerted in the State or municipal schools for obvious reasons, there is no arbiter to determine where economic truths leave off and where political truths (usually economic fallacies!) begin. This influence cannot be effectively exerted by the employer as he is not always regarded as unprejudiced. But the industrial engineer is himself a "worker," in some cases he is (in a sense) no more than a superior wage earner; his interests are of a similar character to those of the men under him, or the men in the direction of whose labour he occupies himself. By keeping in close personal touch with the rank and file he may exert considerable influence, and, apart from his quasi-professional duties, by utilising every opportunity, he may become a great force in the wider education of the masses throughout the length and breadth of the land. The experience of industries under the stimulating influence of the great war has awakened attention to the question of economic production to an extent which no lesser cataclasm could have done; it is for those who have the interests of our engineering industries at heart to see that we do not fall back into the old state of lethargy, and that public attention which events have fastened, or focussed, on to this vital question of efficient production is not allowed to sleep or even to become relaxed until those abuses which have been eating like a canker into the heart of our industrial life have been finally overcome and removed.

A METHOD OF DETERMINING THE DENSITY OF FLUE GASES.*

BY JAS. ALEX. SMITH.

ENGINEERS, whether power, metallurgical, or manufacturing, can always ascertain the density of the gases within their province, either by chemical analysis or precision weighing. But it is not always essential to know the chemical composition; or the composition may be deducible with sufficient accuracy if the density is known. The methods of a simpler or more direct character have a use, particularly when it is desired to study cause and effect concurrently, and without any appreciable intervening interval during which the cause might vary. The purpose of this paper is to describe a mode of determining gas density by gauge reading. So far as the writer is aware, the method is new.

General Principles.—The basic theorem is that the densities of gases and their pressures per unit area of base are directly proportional when the gas columns are of equal height. Hence, if a column of air in a vertical tube of known height is displaced by a given gas, the barometric and thermometric conditions remaining constant, the densities are in the simple ratio

$$D = \frac{P \pm P'}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

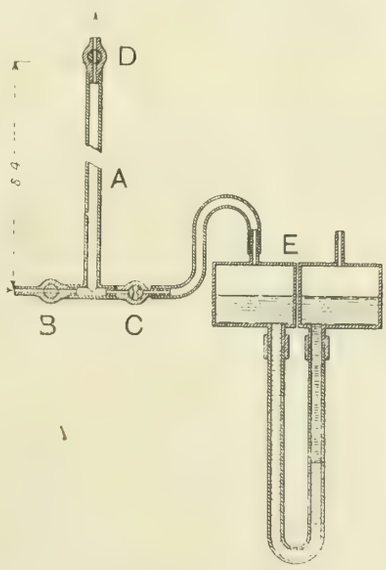
when

D = Density of the given gas referred to air taken as unity,

P = Known air pressure due to column height, and

P′ = Difference (±) of pressure due to gaseous displacement.

Pressure Measurement.—Assume that an accuracy within 1 per cent. of the total air pressure due to the vertical or



A—Gas tube. B—Inlet gas cock. C—Gauge cock. D—Outlet gas cock. E Differential gauge.

NOTE. The barometric equalising vent (at D) is not shown. It consists of a piece of clockmaker's "bushing wire," 1in. long and $\frac{1}{16}$in. bore.

column height is required; in other words, that a pressure due to the air in a column the one-hundredth of the height of the column in the given case must be evaluated. This order of minuteness of magnitude at once contra-indicates mechanism subject to friction, and indicates the use of "frictionless" liquid gauges. Postulating that, without the introduction of undesirable complications, 0·02in. is the smallest significant difference of level of such a gauge, then the relation of that minimum gauge space to the minimum correlated gas-tube height (h) is given by the equation

$$h = \cdot 02 \text{ in.} \times 100x \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

when x is the specific gravity of the gauge liquid referred to air as unity. Therefore water, which is about 772 times heavier than air, if used in a simple siphon gauge, and under

* Paper read before the Victorian Institute of Engineers, July 6th, 1916.

the conditions postulated, requires a complementary gas-tube not less than 0·02in. × 100 × 772 = 1,554in. = about 130ft. in height. Conversely, if the height (h) in inches be given, then the maximum specific gravity of the possible gauge liquid (air, as before, being taken as unity) is determined by the formula

$$x = \frac{h}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Any convenient value may be assigned to h. Let, then, the vertical height of the gas column be 100in. Then x = specific gravity 50. That is, for such a tube height, a liquid is indicated not more than 50 times heavier than air, or $\frac{772}{50}$ = 15·44 times lighter than water. No such light liquid is known; but its equivalent may be attained if two immiscible liquids are caused to partially equilibrate each other in such a manner that the difference (which may be made as small as desired) of the specific gravities becomes the measure of the equivalent specific gravity of the liquid system as a whole.

A gauge on the differential principle, capable of readily dealing with gas pressures of the small magnitude in question, has already been described by the author in the "Proceedings" for November, 1909, vol. X., page 155, under the title, "A Simple, Sensitive, Two-Liquid Differential Gauge for Measuring Small Pressures."

Gas Tube.—The gas tube is very simple. In the example illustrated it consists of a piece of ⅛in. wrought-iron gas barrel, A, 100in. in height. At the bottom two stopcocks, B, C, permit alternative connection to a gas source or to a gauge, E. To check diffusion the passage through the latter cock should be reduced to a pinhole. At the top a third cock, D, opening into the air, permits the tube to be gas flushed and filled, and when the main passage is closed continues the connection by a minute by-pass large enough to preclude any possible barometric difference of pressure between the gas inside and the air outside the tube, yet so small that diffusion is negligibly slow. The surface of the liquid in the gauge cistern and the bottom of the gas tube must be approximately at the same level.

Calibration.—If the gauge constants are unknown, a simple, comprehensive calibration covering all the factors can be effected thus: All parts being filled with air, adjust the gauge to zero. Then displace the air in the tube with any easily generated or procured gas of known density, for instance, CO_2, the specific gravity of which is 1·524. Then the pressure upon unit of base of 100in. vertical of CO_2 is equal to the pressure of 100 × 1·524 = 152·4in of air. Therefore, the consequent liquid displacement due to the displacement of the air by gas is equivalent to that which would be caused by an air pressure of 152·4 − 100·0 = 52·4in. The scale can be graduated or interpreted accordingly.

Corrections.—When relativity only is required, corrections may be dispensed with. The case of the immediate effect of draught volume variation upon chimney-gas density is an example. But if absolute readings are required, and if the barometric and thermometric conditions differ from those which may have been assigned in respect to P. (formula 1), and upon which the value of the gauge divisions is computed, then a corrected value P″ must be substituted for observed P′ in formula (1); then

$$P'' = \frac{(461 + t)\ 29{\cdot}92 \times P'}{461 \times b} = \frac{(461 + t) \times P'}{15{\cdot}41 \times b} \quad . \quad . \quad . \quad (4)$$

when

t = Observed temperature on Fahrenheit scale,
b = Observed barometric pressure in inches,
P′ = Observed pressure due to gas displacement, and
P″ = Corrected value of observed displacement pressure.

Strictly, a further correction should be made to compensate for the variation in the gas system volume, due to the movement of the liquid in the gauge. Usually, however, this amount is so small that it may be neglected in practice.

Scales.—The actual graduations may be in any convenient term, *i.e.*, density or specific gravity, percentages, or direct evaluations of the major object of the test.

Variants.—(i) The mode is equally applicable in the case of density change due to chemical reaction other than combustion. (ii) In the case of inconveniently high tubes, all adjustments may be brought within operative reach by constructing the tube as an inverted ∩, providing that the minute equalising vent must then be placed at the vertex, and must remain permanently open. (iii) A gas tube within a chimney and extending to its full height affords a means of ascertaining the density of the chimney gases at the mean temperature within the whole stack. From this may be deduced the potential ascensional power of the gases, a result not given by the ordinary draught gauges, which show the utilised value only. (iv) Obviously portability can be attained by constructing the tube in screwed sections. (v) Photographic continuous records can be attained by the use of any of the well-known devices. This implies a constant passage of gas, therefore precautions must be taken against the vitiation of the results by the introduction of extraneous pressure head, either by periodically cutting off the gas supply, or by making the inlet very small in comparison with a relatively large outlet permanently open. Necessarily there will be a lag in the records in respect to time.

THE UTILISATION OF WASTE HEAT FOR STEAM-GENERATING PURPOSES.*

BY ARTHUR D. PRATT.

THE utilisation of waste heat from various industrial processes for the generation of steam is not new. The advance within the last few years, however, in methods of utilising such gases and in the results secured from their utilisation has been so remarkable as to make of interest a comparison of former with present-day methods and results.

The design of waste-heat boilers has progressed to a point where it is to-day possible to successfully generate steam from gases whose temperatures are as low as 950° Fah. to 1,000° Fah. It is but a few years since it was considered absolutely impracticable from a commercial standpoint to attempt to produce power from such gases, and it is in its ability to satisfactorily utilise these gases that the development of the modern waste-heat boiler has its most far-reaching effect.

The sole theory on which early waste-heat boiler installations were made has as its basis the non-interferences in the operation of the primary furnace. This meant, in practically all cases, that the draught at the exit of the primary furnace should in no way be impeded, and resulted in the installation of a given amount of heating surface arranged in such manner that the frictional resistance to the gases in their passage through the boiler should be a minimum. Presumably the object of such an arrangement was to enable a natural-draught stack of a practicable height to be used. As the result of minimising this draught loss, such boilers as were installed were ordinarily entirely without baffles and the gases were given a straight passage through the boiler, though partially baffled boilers were used occasionally. High exit-gas temperatures were considered rather desirable than otherwise in order to assist the stack in giving the required draughts. Boilers installed in this way were considered practicable only with gases whose temperatures approached those of coal-fired practice. The users accepted the steam generated as "something for nothing" and no particular endeavour was apparently made toward increased capacities.

Present-day waste-heat practice has come about with a more thorough understanding of the laws governing heat transfer and an appreciation of the function of gas velocity as affecting transfer rates. Without going into this aspect, it may be broadly stated that the rate of heat transfer is dependent upon gas velocity and temperature difference between the gas and the absorbing surface. Experiments have shown that at even the highest velocities now used in waste-heat work the effect of increased temperature difference is small as compared with that of increased gas velocity.

In coal-fired boiler practice the average temperature difference between gases and boiler surfaces is approximately 1,150° Fah. The heat-transfer rate corresponding to a boiler's rated capacity is about 3 B.T.U. per hour per square foot of surface per degree difference, or a heat absorption of 3,450 B.T.U. per square foot of surface per hour. In waste-

* Abstract of paper read at the annual meeting of the American Society of Mechanical Engineers, December 5th to 8th, 1916.

heat work the temperature difference varies widely with the class of waste heat. With a gas temperature of, say, 1,250° Fah. entering a boiler, the average temperature difference between boiler surface and gas for a working pressure of 170lbs. per square inch will be about 500° Fah. For such a temperature difference the transfer rate to give an absorption per square foot of surface equal to that of the coal-fired boiler at rating, would have to be 6·9 B.T.U. per hour per square foot per degree difference. This rate is slightly higher than the rates corresponding to velocities that are as yet ordinarily used, but, with somewhat higher entering-gas temperatures, the absorption per square foot of surface is such as to enable a boiler's rated capacity to be developed without difficulty. With gas temperatures entering the boiler of 1,800° Fah. to 2,000° Fah., which approach coal-fired practice, high overloads are being developed.

The gas velocities necessary to give what is now considered a desirable transfer rate lead to a frictional resistance through waste-heat boilers which makes the use of a natural-draught

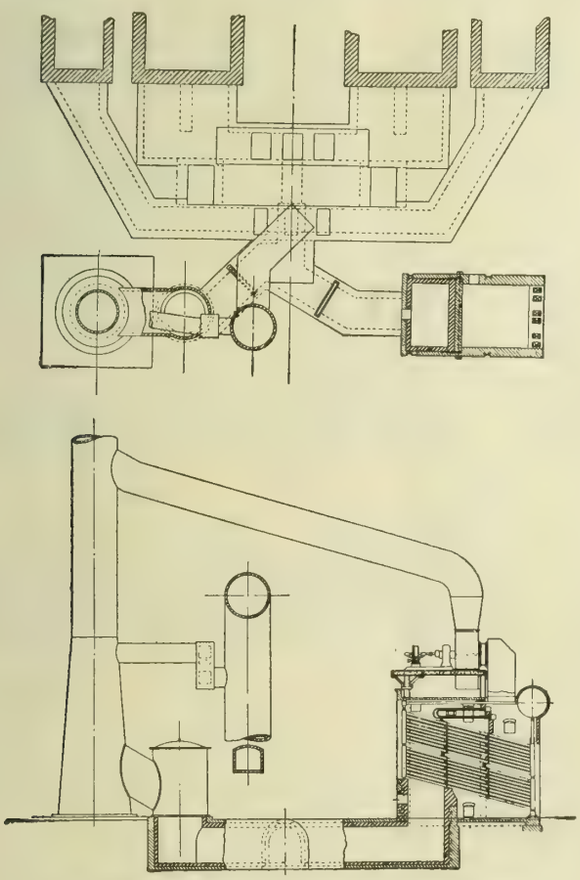


FIG. 1.—WASTE HEAT BOILER FOR OPEN-HEARTH FURNACE.

stack impracticable. Let us consider what is probably the extreme case in so far as draught conditions are concerned, namely, the open-hearth steel furnace. Common practice in this class of work is to use stacks 160ft. high, which give a draught at their base of approximately 1·4in. to 1·6in., depending upon the gas temperatures. For the present purpose, assume that the draught loss through a modern waste-heat boiler installed with an open-hearth furnace is 2·0in., a figure which approximately represents the practice of to-day. With a natural-draught stack, the draught at the checkers corresponding to the 1·4in. to 1·6in. given above is approximately 1·3in. to 1·5in., and this amount is necessary for the proper operation of the furnace. With a waste-heat boiler installed, then, the draught necessary at the exit of the boiler must be sufficient to overcome the resistance through the boiler, 2in., that necessary to overcome resistance through the flues, say 0·75in., and 1·5in. necessary at the checkers, or a total of 4·25in. It is to be remembered that with a waste-heat boiler installed, the temperature of the gases entering the stack, instead of being 1,000° Fah. or 1,200° Fah., will be 450° Fah. or 500° Fah., under which conditions a stack of 160ft. instead of giving a draught of 1·4in. to 1·8in. at its base would give approximately 1·9in., and to give the necessary 4·25in. the stack height would have to be somewhat over 730ft.

While, as stated, this is perhaps the extreme case, the same reasoning applies in practically all waste-heat work, and an induced draught unit is now almost universally used with the modern design of waste-heat boiler. In certain classes of waste-heat work, such a fan not only furnishes the required draught suction, but is of a decided advantage in the operation of the primary surface.

As may be inferred from the foregoing, the successful utilisation of waste gases becomes more difficult with decreasing gas temperatures. It was in connection with regenerative furnaces and low-temperature gases that the principles of high gas velocity were first applied and the modern waste-heat boiler was developed. The success of the early installations in this particular class of work led to the application of this theory to all classes of waste-heat practice.

Waste-heat boilers of the modern design are in successful operation to-day with copper refining furnaces, cement kilns, open-hearth steel furnaces, beehive coke ovens, zinc refining furnaces and heating furnaces of various types, both regenerative and non-regenerative.

As stated, the waste-heat boiler of to-day was developed with low temperature gases, and its largest field, until the present, has been with open-hearth steel furnaces. For this reason this class of waste-heat work is considered first. The following is an abstract of this consideration, and of the sections of the paper devoted respectively to cement kilns, copper furnaces, beehive coke ovens, heating furnaces, and miscellaneous, including zinc furnaces, nickel-refining furnaces, gas benches, and oil stills.

Open-hearth Steel Furnaces.—Under this heading the paper describes in detail certain features of installation and operation, some of which refer specifically to open-hearth work, and others to waste-heat work in general. These include location of boilers, connecting flues, air leakage, cleaning, dampers, and explosions.

The application of waste-heat work to open-hearth steel furnaces may be considered new. In this type of furnace we have the best and by far the most numerous examples of the regenerative furnace. From the very nature of the operation of such furnaces, gas temperatures passing to the stack are low, and the ability of the modern waste-heat boiler to utilise successfully these gases for the generation of steam is, without question, the best proof of the progress in the development of this particular class of boiler.

TABLE I.—*Results of Tests of Waste-heat Boilers for Open-hearth Furnaces.*

Test Number	1[1]	2	3	4
Plant	Illinois Steel Co.	Indiana Steel Co.	Bethlehem Steel Co.	Lackawanna Steel Co.
Location	S. Chicago, Ill.	Gary, Ind.	S. Bethlehem, Pa	Buffalo, N.Y.
Rated capacity of furnace, tons	65	75	80	[5]
Actual production, tons.	72[2]	85	82·6	—
Boiler	Stirling	Rust	B. & W.	B. & W.
Heating surface, sq. ft...	4,000	4,880	5,232	5,407
Superheater, deg. Fah...	128	176	121	97
Gas weight, lb. per hour...	73,000	83,434	75,271	78,947
Gas per hour per sq. ft. heating surface ...	18·3	17·1	14·4	14·6
Temperatures:				
Gas entering boiler, deg. F.	1227	1155	1362	986
Gas leaving boiler, deg. F.	621	530	493	468
Drop in temp., deg. F. ...	606	625	869	518
Draught at boiler inlet, in.		1·47	1·55	1·76
Draught at boiler damper, in.	—	3·95	3·29	3·63
Draught loss, in.	1·78	2·48	1·74	1·87
Gross h.p. developed ...	334·5	393	425·8	306
Per cent. of rated capacity[6]	83·6	80·6	81·4	56·7
Boiler h.p. to fan ...	[3]	60[4]	24·3[3]	-
Net horse-power		386	401·5	
Approx. transfer rate (*R*)	5·08	6·92	4·77	5·12

[1] Average of ten tests. [2] Approximate. [3] Motor-driven fan. [4] 53 h.p. returned in feed-water heater. [5] Tilting furnace. [6] All ratings on basis of 10 sq. ft. per horse-power.

Four installations of waste-heat boilers for open-hearth furnaces are described—one of two Stirling boilers at the plant

of the Illinois Steel Company, one of 28 Rust boilers at the Indiana Steel Company, one of Babcock & Wilcox boilers at the Bethlehem Steel Company, and one of Babcock and Wilcox boilers at the Lackawanna Steel Company. Results of tests of these installations are compared in Table I. A typical successful layout of waste-heat boilers for this class of work is illustrated in Fig. 1.

Cement Kilns.—The use of waste-heat boilers in the cement industry is not, strictly speaking, new. The number of installations, however, has been extremely small, and there appear to have been several reasons for the non-development of such boilers in this field. Reference is made to several installations of waste-heat boilers with cement kilns, the first of which are typical of early waste-heat practice while the last is representative of the modern design of this class of boilers. Results of tests of these installations are given, from which the advantages of the modern waste-heat design are shown.

Copper Furnaces.—The copper furnaces with which waste-heat boilers have been installed may be classed under two general heads: smelting furnaces (matte furnaces) and refining furnaces. Both classes are fundamentally the same in design, though for metallurgical reasons dimensions of the two classes and individual furnaces in the two classes are varied considerably. Experiences of the Anaconda Copper Mining Company with Stirling boilers, of the Cananea Copper Company with Stirling and Aultman and Taylor boilers installed with copper smelting furnaces are described, and also those of the Baltimore Smelting and Refining Company with Stirling boilers utilising the waste heat from copper-refining furnaces. Other refining companies followed the Baltimore Company in this practice, and the author is familiar with over 11,000 h.p. of boilers with refining furnaces alone.

Beehive Coke Ovens.—This class of waste heat is considered because of the very remarkable results being secured from modern waste-heat boilers utilising gases from beehive ovens, and because of the possibilities of saving, due to this utilisation, until such time as beehive ovens are replaced (with by-product ovens). Furthermore, there are available figures from boiler installations made a number of years ago for this class of work, and from a comparison with the results to-day the great advance in the design of waste-heat boilers may be readily seen.

Even granting that beehive ovens will ultimately be replaced with by-product ovens, the author considers that, in numerous plants, an installation of waste-heat boilers would pay for itself many times before such a change could be made, and that it would be entirely possible, too, in these installations to design the boilers in such a manner that at the time of replacing the beehive ovens the boilers could be dismantled and reset either for burning coal or coke breeze, or to be fired with by-product coke-oven gas.

Heating Furnaces.—The early history of waste-heat boilers applied to heating furnaces is in reality the early history of the utilisation of waste heat in general. The early designs of boilers in most general use in this class of work are described and illustrated, this being followed with a description of the first waste-heat boilers of the strictly modern design and utilising the theory of high gas velocity, these boilers being installed by the Bethlehem Steel Company.

While by far the greatest number of waste-heat boilers in service are in the industries outlined above, there are numerous installations in plants of different character. In this miscellaneous class, while the number of installations in any single industry is small, reference is made to certain of these to give an idea of the wide and varied field for development in the use of waste heat.

Prizes for Essays.—The Governors of the Royal Technical College, Glasgow, at the request of certain donors, offer prizes, amounting to £70, for essays on the best methods of training, and employing in industries, other than agriculture, returned soldiers and sailors, maimed or otherwise. The prizes will be awarded by a Committee of the Governors, and may be withheld in the event of no essay of sufficient merit being submitted. The decision of the Committee on this and all other points will be final. Essays must be sent in not later than March 1st, 1917, addressed to the Director, the Royal Technical College, Glasgow.

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Methods of and apparatus for producing asymetric waves of electromotive force. British Westinghouse Electric and Manufacturing Company. 9927.

The John Fritz Medal.—This medal was recently presented to Dr. Elihu Thomson for "Achievements in Electrical Inventions, &c." The medal is awarded from time to time for notable scientific or industrial achievements, and was provided for in a fund subscribed in memory of the engineering pioneer, John Fritz.

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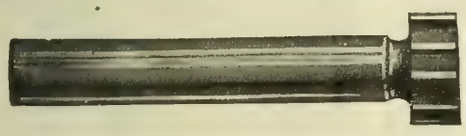

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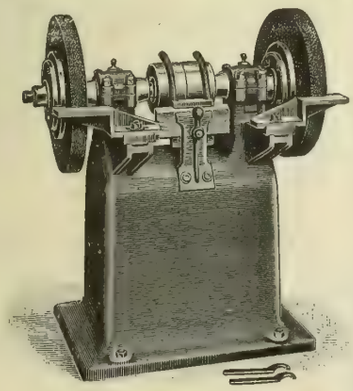

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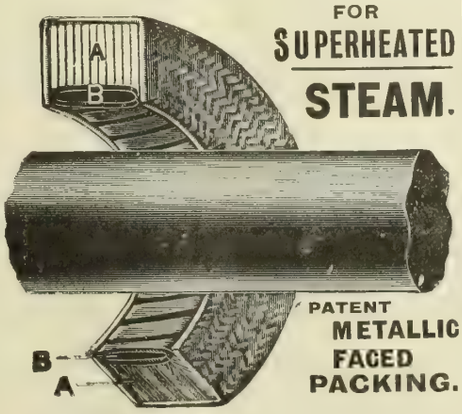

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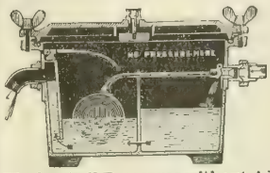

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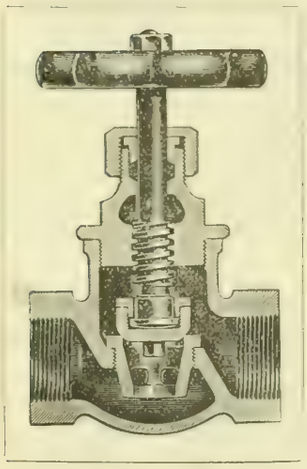

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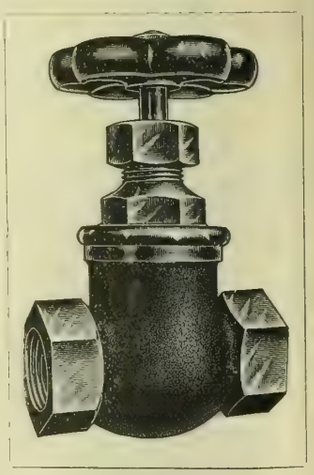

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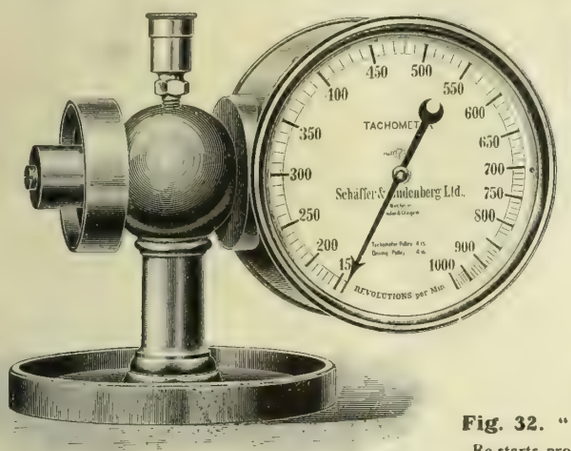
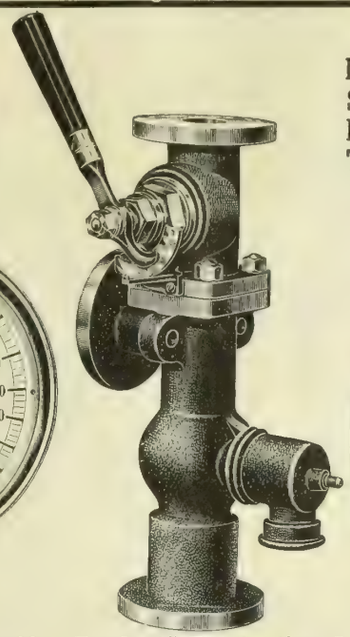


Fig. 11. Tachometer.



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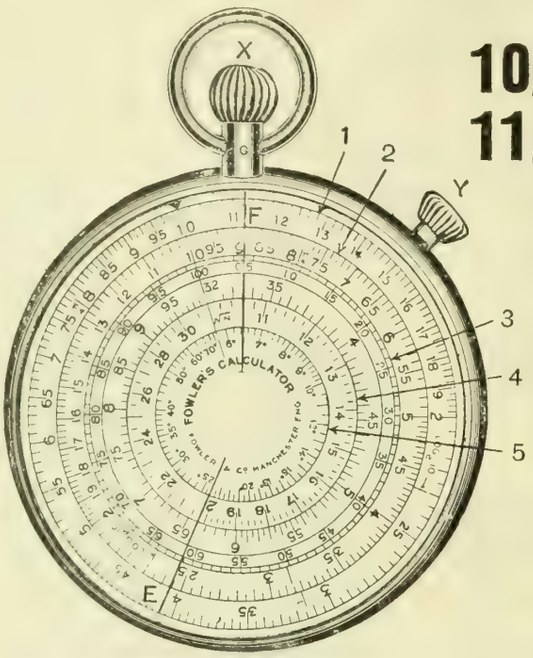

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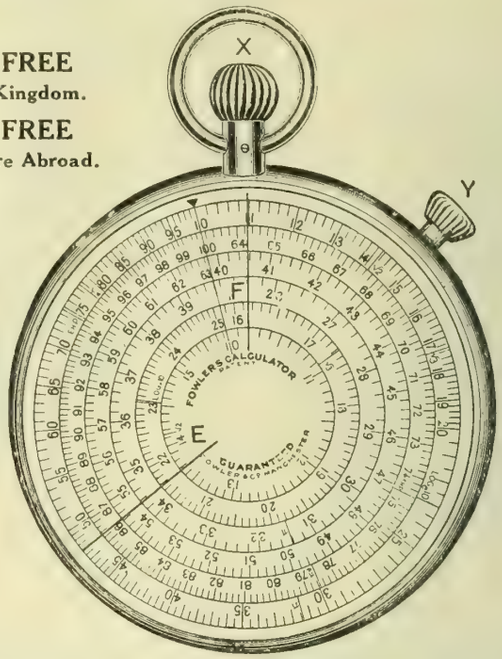

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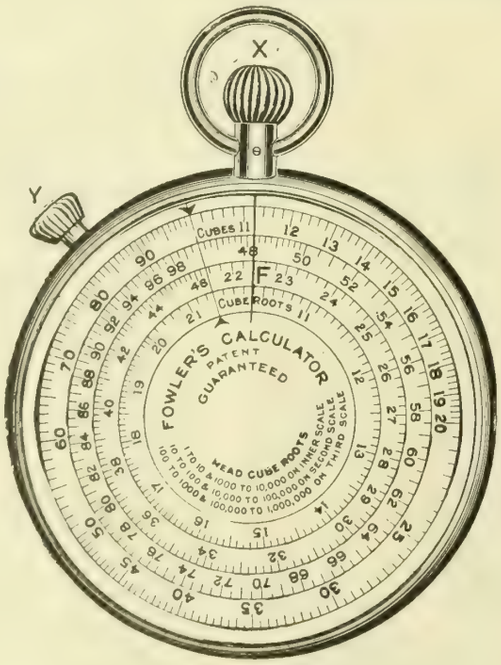
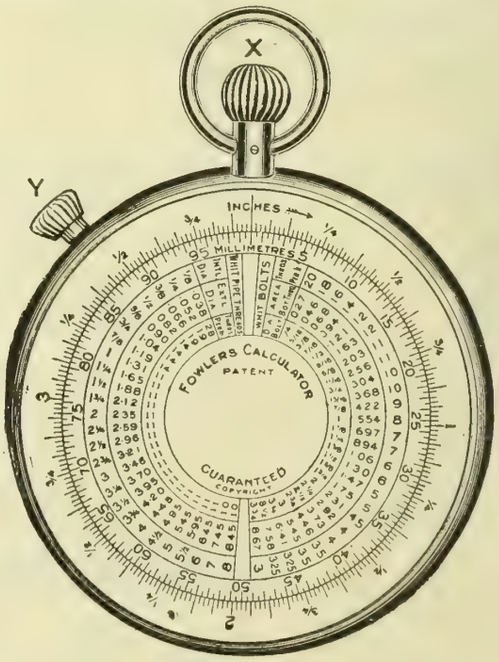


Fig. 3.—Cube Root Back Dial.



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CONTENTS.

	PAGE
Hardness Tests	493
Book Reviews	494
Books Received	494
Davey's Compound Condensing Pumping Engine	495
Liquid Measuring Pumps	496
Report of the Hardness Tests Research Committee	497
Mechanical Design of Electric Locomotives	501
Preventing the Corrosion of Pipe	502
Nelson's Gas Producer	504
Aluminium	505
The Economic Outlook and the Labour Problem	506
A Method of Determining the Density of Flue Gases	509
The Utilisation of Waste Heat for Steam Generating Purposes	510
New Patents	512

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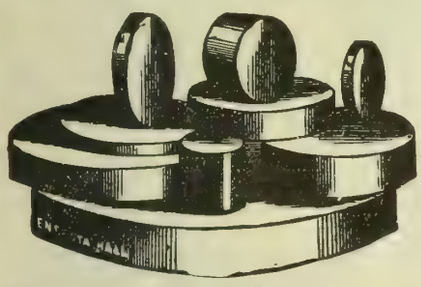

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INDEX TO ADVERTISERS.

	PAGE
Automatic Standard Screw Company, Halifax	
Bailey & Co., Sir W. H., Ltd., Salford	
Bridge & Co., D., Ltd., Manchester	x.
British Engine, Boiler, and Electrical Insurance Company, Ltd., Manchester	iii.
Brown Bayley's Steel Works, Ltd., Sheffield	
Caxton Publishing Company, Ltd., London	
Coventry Chain Co., Ltd., Coventry	
Coventry Ordnance Works, Ltd., Coventry	i.
Davidson & Co., Ltd., Belfast	
Delta Metal Company, Ltd., London, E.C.	i.
Dermatine Company, Ltd., London	
Fairley & Sons, James, Ltd., Birmingham	v.
Firth & Sons, Thos., Ltd., Sheffield	
Fowler & Co., Manchester	iv
Foyle, W. & G., London	
Gardner & Sons, L., Ltd., Patricroft	vi.
Green & Son, E., Ltd., Manchester	
Griffin & Co., Charles, Ltd., London	
Guilbert-Martin, London	
Hadfield's Steel Foundry Company, Ltd., Sheffield	vii.
Harlow & Sons, R., Stockport	ii.
Ingersoll-Rand Company, London	
Jones, George, Ltd., Birmingham	
Kirby Banks Screw Company, Ltd., Leeds	x.
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Lancaster & Tonge, Ltd., Pendleton	i.
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Sugden, T., Ltd., London	vi.
Thornton, A. G., Manchester	
Tinker, Shenton, & Co., Ltd., Hyde	
Trier Bros., London	
Turner & Co., J. E., Ltd., Bradford	493
Turner Bros., Ltd., Rochdale	
United Flexible Metallic Tubing Company, Ltd., London	493
United States Metallic Packing Company, Ltd., Bradford	viii.
Wailes Dove Bitumastic, Ltd., Newcastle-on-Tyne	xi.
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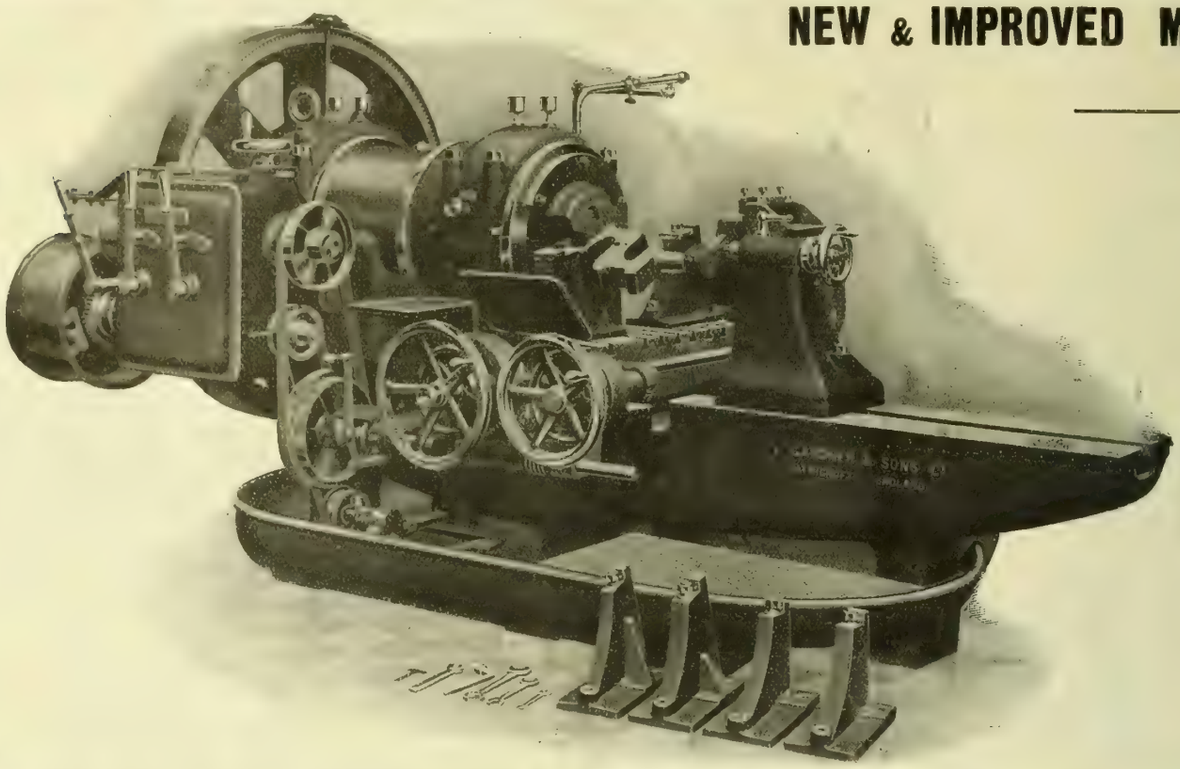

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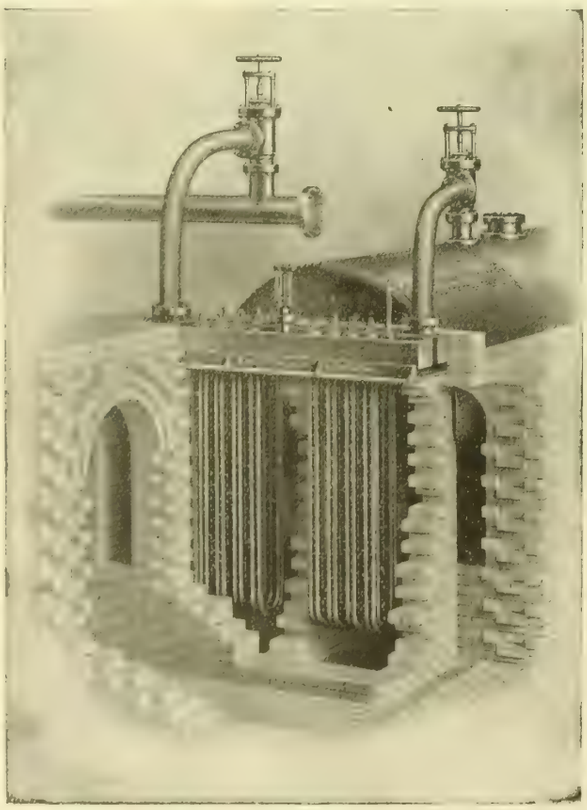

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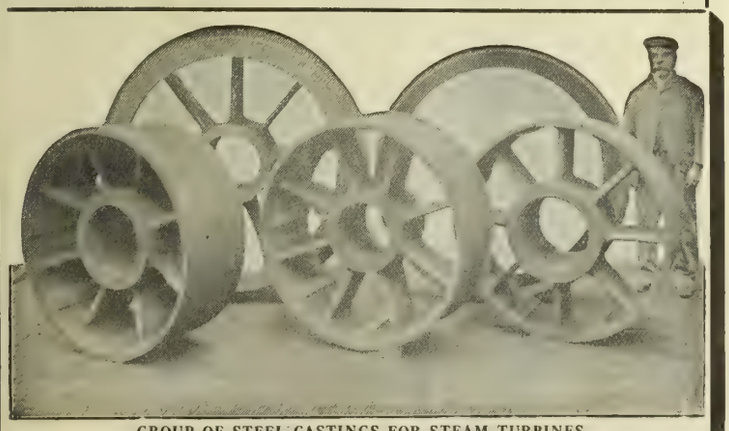

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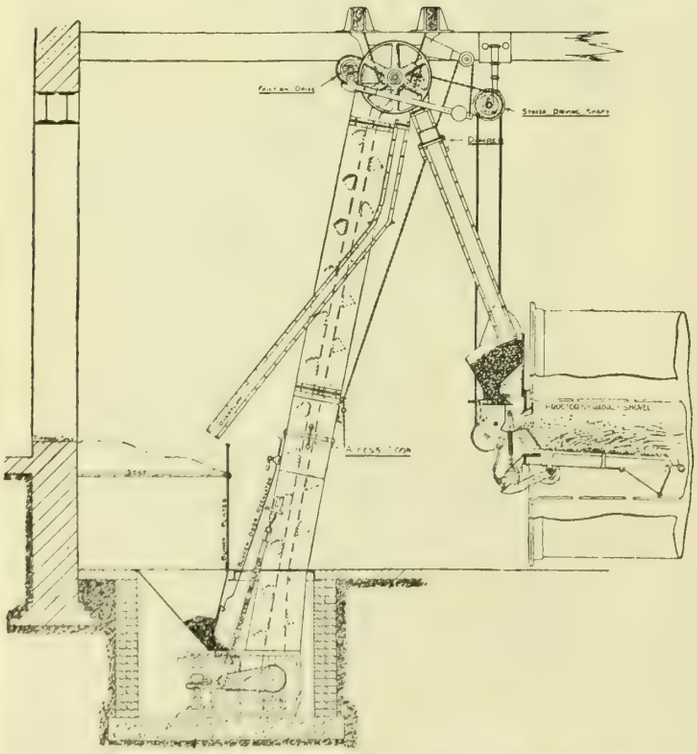

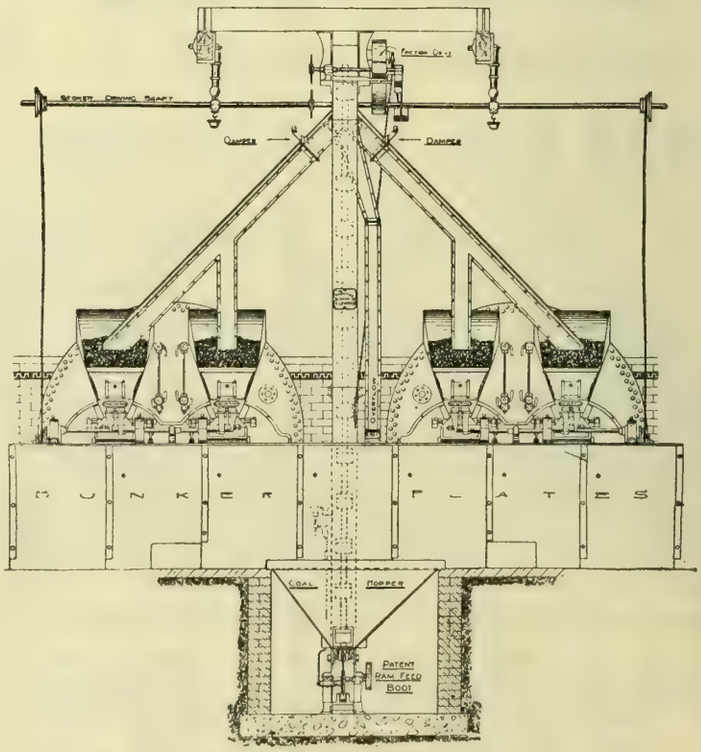

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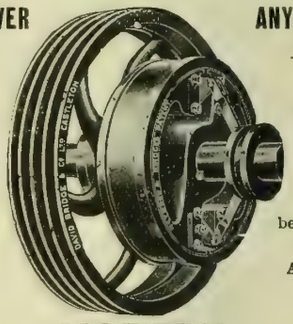

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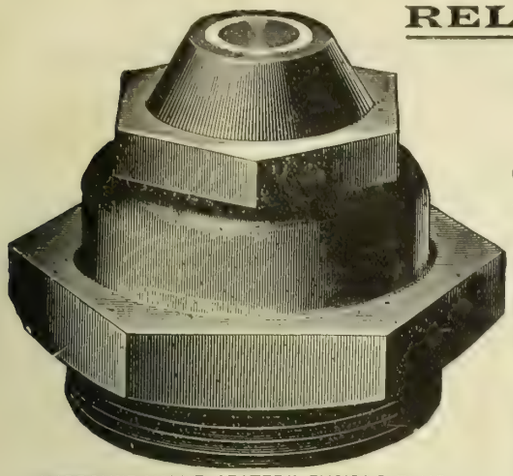

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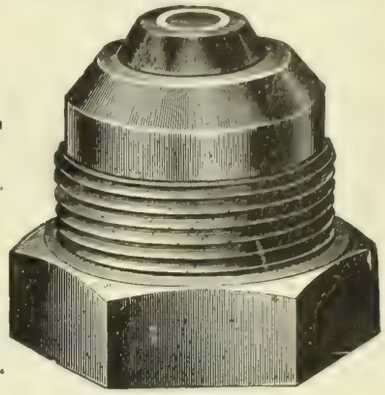

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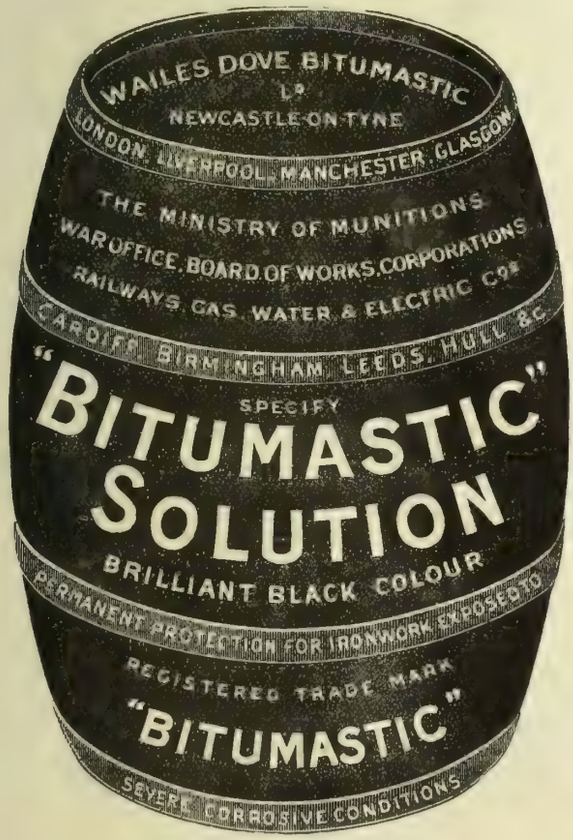

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